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Physical education, health and education innovation, 2^{nd} edition

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Editorial: Physical education, health and education innovation

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Editorial on the Research Topic
Physical education, health and education innovation

Physical Education is closely linked with the overall health of individuals, with education, and with educational innovation essential aspects for shaping the development of individuals within the educational context. Thus, these aspects form part of the educational process, which encompasses knowledge from applied psychology to education. Examples include the analysis of motivation in the teaching-learning process, the analysis of physical exercise behavior, and adherence to sports practice at early ages. In this context, various studies highlight the importance of interventions among children and adolescents to promote physical fitness due to its relationship with adequate physical aptitude, motor skills, and overall wellbeing in later stages (young adulthood, adulthood, and even older adulthood). For instance, in the meta-analysis by Li H. et al., it was observed that physical fitness and basic motor skills interventions improved these capacities and skills with sessions lasting 60 min, practiced 1–3 days a week for at least 16 weeks. Along the same lines, Chen J. et al. report on the importance of interventions through movement during preschool stages. These authors conclude that physical fitness and fundamental motor skills mutually enhance each other in young children, and both should be emphasized in preschool sports education. Similarly, the development of motor literacy can be crucial for engaging in physical activity over the years, finding that individuals with higher motor competence across various dimensions also show higher levels of moderate to vigorous physical activity (Martinez-Lopez et al.). Thus, there is a need to promote the development of motor competence to increase the rate of physical activity and sports activities among schoolchildren.

Regarding adolescence, the educational context could be decisive in the levels of physical exercise practice and its impact on normative behavior, as suggested by Chen H. et al.'s study where the use of the STEAM teaching method improved engagement with learning. Additionally, the study by Rojo-Ramos et al. found that in adolescence and pre-adolescence, higher self-efficacy is associated with lower levels of abuse and victimization, positioning regular physical activity as a mediator for preventing cyberbullying.

In relation of the concept of innovation, responsible and proportionate use of virtual reality could foster a positive attitude among basketball players and achieve professional success in the classroom, as indicated by Wang. Other studies, such as Guijarro-Romero et al., evaluate the use of technologies, for example, the inclusion of activity bracelets and behavior modification techniques in training activities. These authors found highly satisfactory results, as they support perceived autonomy and increase physical activity levels among adolescents. Similarly, Chow and Mann shows that 'exergaming' or games promoting physical activity through technology could contribute to improving healthy habits. Their study is based on a theoretical model using Bloom's taxonomy to obtain resources for future research on exergaming.

In the field of Physical Education, small-sided games allow high-intensity physical activity in classes flexibly and motivatingly, with many possibilities for class design and application across different sports (Li Q. Z. et al.). Thus, educational innovation is necessary within Physical Education through model hybridization, as evidenced by Quiñonero-Martínez et al. study, with positive results toward creating habits related to physical activity. Similarly, the use of alternative sports, as shown in Diez-Fernández et al. study with the practice of "cornerball," is an appropriate alternative for promoting sports in different ways. Teaching artistic activities and not just sports can also greatly benefit students by improving aspects such as self-efficacy and self-esteem in young students (Zhou et al.). Moreover, scientific literature indicates that achieving higher academic performance necessitates appropriate physical activity, finding that students who run at least once a week excel academically with a sample of over 2200 university participants (Du et al.).

Finally, innovation should be present not only in Physical Education classes but also in the sports field, developing intervention program like the Real Madrid Foundation (RMF) by Ortega-Vila et al., which show conclusive results toward personal and team success, self-fulfillment, personal and group superiority, health, and physical fitness.

Another essential aspect of the educational process, along with psychology, physical exercise behavior, and innovation, is teacher training to integrate all these concepts for the overall health development of schoolchildren and adolescents. Hence, developing theoretical models to improve the communication skills of teachers and physical trainers and providing them with didactic resources to foster learning climates based on more self-determined motivation is important (Chen L. et al.). Since motivation drives human behavior, it is necessary to understand how to internally motivate children and adolescents, especially from early ages, to foster values such as personal and social responsibility and the intention to engage in physical activity in the present and future (Manzano-Sánchez). Closely linked to motivation, emotional intelligence could influence increased life satisfaction and reduced anxiety levels, making its study essential. It seems that clarity and emotional repair variables can act as mediators, reduces the negative effects of anxiety (Calleja-Núñez et al.). Other psychological aspects that explain human behavior, such as personality traits, are fundamental in Physical Education classes, as they can predict satisfaction with classes, as indicated by Chen Z. et al. in older students.

Finally, it is important to consider the age and sex of students, as these aspects can influence the degree of physical activity, making it advisable to implement study plans that address these differences in Physical Education classes, investing in appropriate facilities and materials (Ma et al.).

Author contributions

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Exergaming and education: a relational model for games selection and evaluation

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Exergaming, or technology-driven physical exercise, has gained popularity in recent years. Its applications include physical education, health promotion, and rehabilitation. Although studies have obtained promising results regarding the positive effects of exergaming, the outcomes of exergaming for different populations remain undetermined. Inconsistencies in the literature on this topic have multiple potential explanations, including the content and demand of the exergames and the capability of the exergamer. A model with a sound theoretical framework is required to facilitate matching between games and gamers. This article proposes a relational model based on a matrix of Bloom's taxonomy of learning domains and the performance components of exergames. Appropriate matching of the physical demands of an exergame and the ability of the exergamer would enhance the effective usage of exergaming for individuals with various needs. This theory-based exergame model is developed to promote the general development, physical status, and psychosocial well-being of students, older adults, and individuals with rehabilitation needs. This model may provide a resource for future research on the application, effectiveness, and design of exergaming.

KEYWORDS

model of exergame, Bloom's taxonomy, exergame selection, health and well-being, education

Introduction

Exergaming has recently gained popularity among children and adolescents (Benzing and Schmidt, 2019; Milajerdi et al., 2021). A survey in Norway indicated that in 2020, 96% of boys and 76% of girls reported playing video games regularly, whereas the corresponding figures were 96 and 63% in 2018 (Norwegian Media Authority, 2020). A study in Canada involving 1,241 students in grades 10 and 11 revealed that 24% of the participants reported exergaming, and they played an average of 2 days per week for approximately 50 min each session (O'Loughlin et al., 2012).

Exergaming combines exercise and gaming and can also be called active video gaming. Advances in digital gaming technology have enabled a player's body movements to replace the button presses of traditional sedentary gaming. Video gaming technology has advanced from motion-sensing handles to optical sensors that allow for more realistic whole-body movement. This development has prompted researchers to explore the potential applications of exergames and active video games in physical education (Annetta, 2008; Papastergiou, 2009; Staiano and Calvert, 2011; Perlman et al., 2012; Rüth and Kaspar, 2021), health promotion (Biddiss and Irwin, 2010; Emara et al., 2020), clinical rehabilitation (Anderson-Hanley et al., 2011; Chen et al., 2012; Howcroft et al., 2012; Vieira et al., 2021), and cognitive training (Green and Bavelier, 2012; Kiili and Perttula, 2012; Kolovelonis et al., 2023). Studies have demonstrated the potential beneficial effects of exergame interventions on physical rehabilitation for conditions such as Parkinson's disease and stroke (Harris et al., 2015; Ribas et al., 2017; Cikajlo et al., 2020).

The present study defined exergaming, reviewed current research findings on its effects on different population groups, and recommended further research on its optimal use as an educational and physical exercise tool. We argued that exergaming is a beneficial tool that can (1) increase the level of physical exercise of the general public, (2) promote learning and physical education in students, and (3) facilitate rehabilitation. These purposes can be better achieved if the demands of exergames complement the player's ability. Therefore, this study proposes a model with a multidimensional perspective to ensure precise matching of the demands of an exergame and the player's ability.

Scope of exergaming

Promotion of exercise in children and adolescent gamers

One of the most widely recognized benefits of exergaming is its promotion of physical activity in children and adolescents (Daley, 2009; Biddiss and Irwin, 2010; Gao and Xiang, 2013). The growing global childhood obesity rate has attracted the attention of numerous experts. Insufficient physical activity is a primary cause of this trend (WHO Consultation on Obesity, 2000; World Health Organization, 2021). In contrast to traditional sedentary video games, exergames provide enjoyment and modest levels of physical exercise for players. Exergames offer physical benefits to children and foster sports-related interests and skills (Staiano and Calvert, 2011). Exergame players have a light to moderate level of energy expenditure, which is twice that of sedentary video game players (Lanningham-Foster et al., 2006; Maddison et al., 2007; Biddiss and Irwin, 2010; Ramírez-Granizo et al., 2020). In addition, different researches on children who participated in a graded exercise test indicated that high-intensity exergaming can increase heart rate and energy expenditure, which can affect vascular function and arterial adaptations in children (Mills et al., 2013; Chen and Sun, 2017). A randomized controlled trial revealed a small but definite effect of exergaming on body mass index and body composition in obese children (Maddison et al., 2011). These results indicate that exergaming is an adequate alternative to physical activity.

Physical and psychological benefits of exergaming

Exergaming was demonstrated to improve children's executive functioning (Kolovelonis et al., 2023). One study showed that an exergame involving repetitive physical activity similar to jogging on a treadmill enhanced children's ability to resolve interference from conflicting visuospatial stimuli (Best, 2012). These effects were noted both in children and in older adults. A meta-analysis indicated that exergaming improved several functions in older adults, such as cognition, motor function, and balance (Fernandes et al., 2022). Another group of adult trainees who engaged in 24 sessions of 1-h exergame training had significantly greater improvements in their measures of physical function and their cognitive measures of executive control and processing speed than control participants did (Maillot et al., 2012).

Many exergamers experience enjoyment when playing. In addition, exergaming, as an alternative form of physical exercise, promotes psychological health. A study revealed that exergaming significantly improved reaction time, subjective happiness, and mental well-being in young adults (Hastürk and Munusturlar, 2022). Another study of 168 college students revealed that exergaming had short-term (approximately 10 min) but not immediate benefits compared to sedentary activity (Russell and Newton, 2008). In addition, exergaming promotes exercise self-efficacy. A study on the effects of group exergaming revealed that adolescents with obesity who participated in a dance-based exergaming group had significantly enhanced self-reported exercise competence and improved relationships with their parents (Wagener et al., 2012). One study indicated that exergaming helped alleviate depression (Li et al., 2016).

Traditional video games also have significant positive effects on multiple health-related outcomes. One review indicated that sedentary video games improved 69% of psychotherapy outcomes, 59% of physical therapy outcomes, 50% of physical activity outcomes, 42% of health education outcomes, 42% of pain control outcomes, and 37% of disease self-management outcomes (Primack et al., 2012). Although no study has analyzed the effects of exergaming on these outcomes, similar effects can be reasonably predicted.

Pitfalls of exergaming

Although considerable evidence indicates that exergames enhance physical and psychosocial health in children, some researchers hold opposite opinions. A naturalistic study investigated whether children playing a new exergame spontaneously engaged more in physical activity than those playing a sedentary game; the evidence did not indicate that children playing active video games were more active in general (Baranowski et al., 2012). This result also raises the question of whether exergaming can affect the long-term physical health of children.

A review of 14 descriptive studies, one uncontrolled trial, and two pilot randomized controlled trials concluded that evidence remains mixed on the subject. No adequately powered randomized controlled trial has assessed the long-term effects of exergaming on children's health (Daley, 2009).

Rüth and Kaspar (2021) described multiple potential critical pitfalls of exergaming, which included the following: (1) unhealthy exercise due to inappropriate training intensity; (2) negative motivational, emotional, and cognitive effects of the competitive mode that hamper physical activity or cause undesirable side effects; and (3) experiences that are not shared or considered worthy of discussion. When exergaming is used as a form of physical education, education- and health-related topics are not discussed during the exergame. Opportunities for communication are limited, and discussion may result in conflicts with others.

These drawbacks may not result from exergaming itself but from the selection of exergames. The content and difficulty level of a game may result in improper matching with the gamer's ability, which may affect the usage of exergaming.

Choice of exergame

Exergames are interactive and provide physical exercise and workouts rather than promoting the behaviors (e.g., fighting) of traditional sedentary video games. Thus, whether exergames also produce the negative effects of conventional video games remains unclear. Although studies have reported the negative effects of video games, no studies are known to have reported the adverse effects of exergaming.

Some authors have contended that employing video games as a learning mode can be more enjoyable and stimulating than traditional modes of teaching and learning (Prensky, 2001; Gee, 2003; Kiili and Perttula, 2012). Teachers have employed video games for textbook replacements, homework assignments, and virtual learning (Annetta, 2008). Exergaming is an appealing educational tool for children and adolescents. Nevertheless, because of the mixed results on the effects of exergaming, additional research should investigate factors such as players' preferences and the difficulty levels of games (Daley, 2009).

Empirical research on why and how games affect students is essential as exergaming gains attention and popularity in education. Therefore, the present study constructs a classification system for exergames to facilitate future research and to effectively incorporate exergaming into educational contexts.

Classification of exergames

Studies have classified video games by function, form, and genre (Solomon, 1984; Rebetez and Betrancourt, 2007; Sheehan and Katz, 2010). Solomon (1984) proposed a classification of video games that includes (1) simulations (the game reflects reality), (2) abstract games (the game itself is the focus of interest), and (3) sports. Another study classified video games into six types, namely (1) general entertainment, (2) educational, (3) fantasy violence, (4) human violence, (5) nonviolent sports, and (6) sports violence (Funk and Buchman, 1996).

The Exergame Network, an international collaboration of health and fitness practitioners, exergame developers, and researchers, proposed the following five basic types of exergames: (1) workout exergames—the player completes a workout based on the advice of the game; (2) control exergames—the player uses different body parts to control the game; (3) exergame machines—the player uses real fitness equipment to play the game; (4) sensory exergames—the player must jump and run to earn points; and (5) rhythm exergames—the player becomes a musician or dancer and is guided by music (The Exergame Network, 2012). This system classifies exergames by their motion and perception demands on the player and may be inadequate for enabling exergame adoption in children's education.

Exergames must be individualized and tailored to the target population to yield the greatest benefit (Mishra et al., 2016). Because individualized exergame designs are complex and costly, developing a comprehensive model to facilitate the tailoring of exergames is essential.

Components of exergames from a learning perspective

A growing number of scholars have recommended using exergame learning applications, particularly in physical education (Fogel et al., 2010; Staiano and Calvert, 2011; Best, 2012; Kiili and Perttula, 2012; Ramírez-Granizo et al., 2020). Learning objectives are required when exergames are used as a learning and teaching tool. They are the building blocks of conceptual knowledge and the skills that help students develop understanding and strength.

Bloom (1956) proposed a taxonomy that classifies learning into three separate domains, namely the (1) cognitive domain, (2) affective domain, and (3) motor domain (Forehand, 2005; Huitt, 2011; Hoque, 2016). It is a model to categorize and organize different levels of learning. Cognitive domain includes intellectual skills and abilities related to knowledge, understanding, and thinking. It is further divided into six levels, which are remembering, understanding, applying, analyzing, evaluating, and creating (Huitt, 2011). Affective domain, on the other hand, includes emotional and social skills and abilities related to attitudes, values, and beliefs. It focuses on how students develop feelings, interests, and attitudes toward learning, and how they interact with others. The affective domain is divided into five levels, which are receiving, responding, valuing, organizing, and characterizing (Savickiene, 2010). About the psychomotor domain, it includes physical skills and abilities related to movement, coordination, and dexterity. The psychomotor domain is less commonly used than the cognitive and affective domains but is relevant for subjects that require hands-on skills or physical activity. The psychomotor domain is divided into six levels, which are perception, set, guided response, mechanism, complex overt response, and adaptation (Begam and Tholappan, 2018).

By including all three domains in education planning, it is able to create a holistic approach to learning that addresses not only the intellectual but also the emotional and physical aspects of student development. This can lead to a more comprehensive and effective educational experience for learners (Krathwohl, 2002; Halawi et al., 2009; Seaman, 2011).

The present study employs Bloom's taxonomy as a framework to analyze the effects of exergaming on exergamers (Cooper and Higgins, 2015). The primary purpose of broadening exergame use in learning is to enhance motor, cognitive, and emotional–social skills. A multidimensional perspective should be employed to analyze the potential uses of exergaming. Precise matching between the demands of an exergame and the ability of the exergamer is crucial.

Subdivision of the learning domains can provide a detailed framework for the analysis of exergame demands (Figure 1).

The ability to control voluntary muscle movement is critical to motor development. Motor skills are generally divided into gross and fine skills; gross motor skills involve the use of large muscles in the arms, legs, and torso, and fine motor skills involve the precision, dexterity, and coordination of the hands and fingers (Logan et al., 2018). The motor domain of this model comprises three basic performance components: (1) gross motor skills, (2) fine motor skills, and (3) perceptual motor skills (Bayley, 1999; Frost et al., 2012). These abilities encompass the fundamental motion and coordination demands of exergaming and are also key aspects of physical development. Gross motor skills include balance and coordination, posture control, and whole-body movement, skills that are commonly required in many exergames (Reynolds et al., 2014).

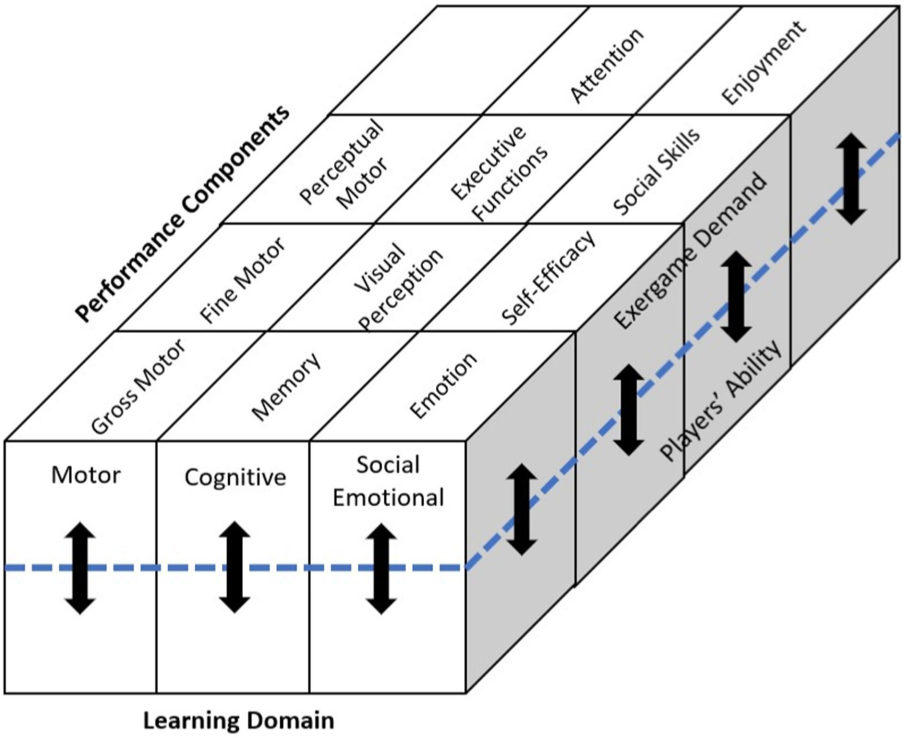

FIGURE 1
Matrix of learning domains, performance components, and matching between demands of exergame and ability of exergamer.

Cognitive development, evidenced by one's ability to think and understand, results from information processing, concept formation, perceptual skills, language learning, and other brain functions (Richardson, 2019). The cognitive domain in our proposed model is divided into the following performance components: (1) memory, (2) visual perception, (3) executive functions, and (4) attention (Greeno et al., 1996). It is unapparent that most exergames demand several cognitive skills. All exergames require a certain level of attention and visual perception. In addition, memory and executive functions are closely associated with the player's response to an exergame (Eggenberger et al., 2020; Zhao et al., 2022).

Social development reflects a child's ability to interact with peers and adults in a socially acceptable manner. Video gamers are not confined to an isolated console but are connected to many other gamers worldwide through the Internet (Kooiman and Sheehan, 2015). This technological advancement imbues exergames with social and emotional elements (Li et al., 2018). The social–emotional domain of the proposed model is divided into the following performance components: (1) emotion, (2) self-efficacy, (3) social skills, and (4) enjoyment (Harris, 1988; Moissinac, 2003). These factors are crucial in the social development of children (Han and Kemple, 2006).

Matching exergame demand and player ability

More vigorous research studies are required because of the growing interest in exergames as educational and rehabilitation tools. Although adverse effects of exergames have not been reported, exercising caution is crucial in the developmental stage. Notably, when adopting exergaming as a teaching and learning tool, the demands of the exergame should be carefully matched with the player's motor, cognitive, and social abilities. The present study's proposed classification system may inform pedagogical practices and provide insight into the integration of exergaming and education. In addition, this model may provide an essential reference for future exergaming regulations prior to its inclusion in education curricula.

Undeniable differences are present between real sports and exergaming. Replacing real sports with exergaming for children requires careful contemplation. The proposed classification system may guide the systematic study of the effects of exergaming and the dissimilarities between real sports and the sport-like activity of exergaming. Many advancements may be made in exergaming hardware and software, and systematic studies of the effects of exergaming should guide such advancements.

The proposed system may contribute to the subsequent development of a standard-level classification system, which can ensure the positive and healthy growth of exergaming. Until now, the adverse effects of exergaming remained unexplored; this study discussed both the positive and negative effects of exergaming on the health and well-being of children. Relevant studies have revealed a trend in the increased use of exergames in the educational context.

Conclusion

This article summarizes the benefits of exergaming on gamers' physical and psychosocial well-being. Although the potential benefits of exergaming have been reported, selecting suitable exergames to match the needs of gamers is crucial to optimize these benefits. This study proposed a model based on a matrix of learning domains, the performance components of exergames, and the matching of the exergame demands with the ability of the exergamer. Based on Bloom's taxonomy (Bloom, 1956) of learning domains, the model enables the proper and effective selection of exergames for various purposes.

An exergame analysis is essential to maximize the benefits of exergaming with respect to rehabilitation and training. A wide variety of highly individualized exergames are commercially available and include multiple therapeutic elements. This study adopted a learning perspective framework to analyze the contents of exergames for multiple reasons. First, exergames have been widely employed to enhance children's physical, cognitive, and mental functioning. An analysis based on a learning perspective is therefore appropriate. Second, for different populations, exergaming can be considered a growth process through which the gamer acquires skills to enhance their overall well-being. Thus, a developmental evaluation would be most appropriate for assessing exergame types.

Finally, the appropriate matching of gamers and exergames may determine the efficacy and effectiveness of exergame training. Some contradictory findings regarding the effectiveness of exergaming are believed to have resulted from inappropriate matching between the needs of gamers and the demands of exergames. Therefore, the proposed theoretical framework for the use of exergames can help maximize the benefits of exergaming.

Author contributions

DC contributed to the conceptual design and model development. SM contributed to the model development and preparation of the manuscript. All authors contributed to the article and approved the submitted version.

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References

Anderson-Hanley, C., Tureck, K., and Schneiderman, R. L. (2011). Autism and exergaming: effects on repetitive behaviors and cognition. *Psychol. Res. Behav. Manag.* 4, 129–137. doi: 10.2147/PRBM.S24016

Annetta, L. A. (2008). Video games in education: why they should be used and how they are being used. *Theory Pract.* 47, 229–239. doi: 10.1080/00405840802153940

Baranowski, T., Abdelsamad, D., Baranowski, J., O'Connor, T. M., Thompson, D., Barnett, A., et al. (2012). Impact of an active video game on healthy children's physical activity. *Pediatrics* 129, e636–e642. doi: 10.1542/peds.2011-2050

Bayley, N. (1999). *Bayley scales of infant development* (*2nd* Edn.). New York: Psychological Corp.

Begam, A. A. A., and Tholappan, A. (2018). Psychomotor domain of Bloom's taxonomy in teacher education. *Shanlax Int. J. Educ.* 6, 11–14. doi: 10.5281/zenodo.1299766

Benzing, V., and Schmidt, M. (2019). The effect of exergaming on executive functions in children with ADHD: a randomized clinical trial. *Scand. J. Med. Sci. Sports* 29, 1243–1253. doi: 10.1111/sms.13446

Best, J. R. (2012). Exergaming immediately enhances children's executive function. *Dev. Psychol.* 48, 1501–1510. doi: 10.1037/a0026648

Biddiss, E., and Irwin, J. (2010). Active video games to promote physical activity in children and youth: a systematic review. *Arch. Pediatr. Adolesc. Med.* 164, 664–672. doi: 10.1001/archpediatrics.2010.104

Bloom, B. S. (1956). *Taxonomy of educational objectives. Handbook I: The cognitive domain*. New York: David Mcjaym Co. Inc.

Chen, H., and Sun, H. (2017). Effects of active videogame and sports, play, and active recreation for kids physical education on children's health-related fitness and enjoyment. *Games Health J.* 6, 312–318. doi: 10.1089/g4h.2017.0001

Chen, P. Y., Wei, S. H., Hsieh, W. L., Cheen, J. R., Chen, L. K., and Kao, C. L. (2012). Lower limb power rehabilitation (LLPR) using interactive video game for improvement of balance function in older people. *Arch. Gerontol. Geriatr.* 55, 677–682. doi: 10.1016/j.archger.2012.05.012

Cikajlo, I., Rudolf, M., Mainetti, R., and Borghese, N. A. (2020). Multi-exergames to set targets and supplement the intensified conventional balance training in patients with stroke: a randomized pilot trial. *Front. Psychol.* 11:572. doi: 10.3389/fpsyg.2020.00572

Cooper, D., and Higgins, S. (2015). The effectiveness of online instructional videos in the acquisition and demonstration of cognitive, affective and psychomotor rehabilitation skills. *Br. J. Educ. Technol.* 46, 768–779. doi: 10.1111/bjet.12166

Daley, A. J. (2009). Can exergaming contribute to improving physical activity levels and health outcomes in children? *Pediatrics* 124, 763–771. doi: 10.1542/peds.2008-2357

Eggenberger, P., Annaheim, S., Kündig, K. A., Rossi, R. M., Münzer, T., and de Bruin, E. D. (2020). Heart rate variability mainly relates to cognitive executive functions and improves through exergame training in older adults: a secondary analysis of a 6-month randomized controlled trial. *Front. Aging Neurosci.* 12:197. doi: 10.3389/fnagi.2020.00197

Emara, A. K., Ng, M. K., Cruickshank, J. A., Kampert, M. W., Piuzzi, N. S., Schaffer, J. L., et al. (2020). Gamer's health guide: optimizing performance, recognizing hazards, and promoting wellness in esports. *Curr. Sports Med. Rep.* 19, 537–545. doi: 10.1249/JSR.0000000000000787

Fernandes, C. S., Magalhães, B., Lima, A., Nóbrega, P., Silva, M., and Santos, C. (2022). Impact of exergames on the mental health of older adults: a systematic review and GRADE evidence synthesis. *Games Health J.* 11, 355–368. doi: 10.1089/g4h.2021.0229

Fogel, V. A., Miltenberger, R. G., Graves, R., and Koehler, S. (2010). The effects of exergaming on physical activity among inactive children in a physical education classroom. *J. Appl. Behav. Anal.* 43, 591–600. doi: 10.1901/jaba.2010.43-591

Forehand, M. (2005). "Bloom's taxonomy: original and revised" in *Emerging perspectives on learning, teaching, and technology*. ed. M. Orey (Scientific Research Publishing Inc.), 41–47.

Frost, J. L., Wortham, S. C., and Reifel, S. (2012). *Play and child development* (*4th* Edn.) Hong Kong: Pearson Allyn Bacon Prentice Hall.

Funk, J. B., and Buchman, D. D. (1996). Playing violent and computer games and adolescent self-concept. *J. Commun.* 46, 19–32. doi: 10.1111/j.1460-2466.1996.tb01472.x

Gao, Z., and Xiang, P. (2013). Effects of exergaming based exercise on urban children's physical activity participation and body composition. *J. Phys. Act. Health* 11, 992–998. doi: 10.1123/jpah.2012-0228

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Comput. Entertain.* 1:20. doi: 10.1145/950566.950595

Green, C. S., and Bavelier, D. (2012). Learning, attentional control, and action video games. *Curr. Biol.* 22, R197–R206. doi: 10.1016/j.cub.2012.02.012

Greeno, J. G., Collins, A., and Resnick, L. B. (1996). "Cognition and learning" in *Handbook of Educational Psychology*. eds. D. C. Berliner and R. C. Calfee (New York, NY: Macmillan), 15–46.

Halawi, L. A., McCarthy, R. V., and Pires, S. (2009). An evaluation of e-learning on the basis of Bloom's taxonomy: an exploratory study. *J. Educ. Bus.* 84, 374–380. doi: 10.3200/JOEB.84.6.374-380

Han, H. S., and Kemple, K. M. (2006). Components of social competence and strategies of support: considering what to teach and how. *Early Child. Educ. J.* 34, 241–246. doi: 10.1007/s10643-006-0139-2

Harris, P. L. (1988). *Children and emotion: The development of psychological understanding*. Oxford: Basil Blackwell.

Harris, D. M., Rantalainen, T., Muthalib, M., Johnson, L., and Teo, W. P. (2015). Exergaming as a viable therapeutic tool to improve static and dynamic balance among older adults and people with idiopathic Parkinson's disease: a systematic review and meta-analysis. *Front. Aging Neurosci.* 7:167. doi: 10.3389/fnagi.2015.00167

Hastürk, G., and Munusturlar, M. A. (2022). The effects of exergames on physical and psychological health in young adults. *Games Health J.* 11, 425–434. doi: 10.1089/g4h.2022.0093

Hoque, M. E. (2016). Three domains of learning: cognitive, affective and psychomotor. *J. EFL Educ. Res.* 2, 45–52.

Howcroft, J., Klejman, S., Fehlings, D., Wright, V., Zabjek, K., Andrysek, J., et al. (2012). Active video game play in children with cerebral palsy: potential for physical activity promotion and rehabilitation therapies. *Arch. Phys. Med. Rehabil.* 93, 1448–1456. doi: 10.1016/j.apmr.2012.02.033

Huitt, W. (2011). Bloom et al.'s taxonomy of the cognitive domain. Educational Psychology Interactive. Valdosta State University. http://www.edpsycinteractive.org/topics/cognition/bloom.html (Accessed 22 May 2023).

Kiili, K., and Perttula, P. T. A. (2012). Exerbraining for schools: combining body and brain training. *Proc. Comput. Sci.* 15, 163–173. doi: 10.1016/j.procs.2012.10.068

Kolovelonis, A., Papastergiou, M., Samara, E., and Goudas, M. (2023). Acute effects of exergaming on students' executive functions and situational interest in elementary physical education. *Int. J. Environ. Res. Public Health* 20:1902. doi: 10.3390/ijerph20031902

Kooiman, B. J., and Sheehan, D. P. (2015). The efficacy of exergames for social relatedness in online physical education. *Cogent Educ.* 2:1045808. doi: 10.1080/2331186X.2015.1045808

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: an overview. *Theory Pract.* 41, 212–218. doi: 10.1207/s15430421tip4104_2

Lanningham-Foster, L., Jensen, T. B., Foster, R. C., Redmond, A. B., Walker, B. A., Heinz, D., et al. (2006). Energy expenditure of sedentary screen time compared with active screen time for children. *Pediatrics* 118, e1831–e1835. doi: 10.1542/peds.2006-1087

Li, J., Erdt, M., Chen, L., Cao, Y., Lee, S. Q., and Theng, Y. L. (2018). The social effects of exergames on older adults: systematic review and metric analysis. *J. Med. Internet Res.* 20:e10486. doi: 10.2196/10486

Li, J., Theng, Y. L., and Foo, S. (2016). Effect of exergames on depression: a systematic review and meta-analysis. *Cyberpsychol. Behav. Soc. Netw.* 19, 34–42. doi: 10.1089/cyber.2015.0366

Logan, S. W., Ross, S. M., Chee, K., Stodden, D. F., and Robinson, L. E. (2018). Fundamental motor skills: a systematic review of terminology. *J. Sports Sci.* 36, 781–796. doi: 10.1080/02640414.2017.1340660

Maddison, R., Foley, L., Ni Mhurchu, C., Jiang, Y., Jull, A., Prapavessis, H., et al. (2011). Effects of active video games on body composition: a randomized controlled trial. *Am. J. Clin. Nutr.* 94, 156–163. doi: 10.3945/ajcn.110.009142

Maddison, R., Mhurch, C. N., Jull, A., Jiang, Y., Prapavessis, H., and Rodgers, A. (2007). Energy expended playing video console gamers: an opportunity to increase children's physical activity? *Pediatr. Exerc. Sci.* 19, 334–343. doi: 10.1123/pes.19.3.334

Maillot, P., Perrot, A., and Hartley, A. (2012). Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. *Psychol. Aging* 27, 589–600. doi: 10.1037/a0026268

Milajerdi, R. H., Sheikh, M., Najafabadi, M. G., Saghaei, B., Naghdi, N., and Dewey, D. (2021). The effects of physical activity and exergaming on motor skills and executive functions in children with autism spectrum disorder. *Games Health J.* 10, 33–42. doi: 10.1089/g4h.2019.0180

Mills, A., Rosenberg, M., Stratton, G., Carter, H. H., Spence, A. L., Pugh, C. J., et al. (2013). The effect of exergaming on vascular function in children. *J. Pediatr.* 163, 806–810. doi: 10.1016/j.jpeds.2013.03.076

Mishra, J., Anguera, J. A., and Gazzaley, A. (2016). Video games for neuro-cognitive optimization. *Neuron* 90, 214–218. doi: 10.1016/j.neuron.2016.04.010

Moissinac, L. (2003). "Affect and emotional development" in *Encyclopedia of education*. ed. J. W. Guthrie, vol. *1. 2nd* ed (New York: MacMillan), 58–61.

Norwegian Media Authority. (2020). *Barn Og Medier-Undersøkelsen [children and media survey]*. Fredrikstad, Norway: Norwegian Media Authority.

O'Loughlin, E. K., Dugas, E. N., Sabiston, C. M., and O'Loughlin, J. L. (2012). Prevalence and correlates of exergaming in youth. *Pediatrics* 130, 806–814. doi: 10.1542/peds.2012-0391

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: impact on educational effectiveness and student motivation. *Comput. Educ.* 52, 1–12. doi: 10.1016/j.compedu.2008.06.004

Perlman, D., Forrest, G., and Pearson, P. (2012). Nintendo Wii: opportunities to put the education back into physical education. *Aust. J. Teach. Educ.* 37, 85–94. doi: 10.14221/ajte.2012v37n7.6

Prensky, M. (2001). *Digital game-based learning*. New York: McGraw-Hill.

Primack, B. A., Carroll, M. V., McNamara, M., Klem, M. L., King, B., Rich, M., et al. (2012). Role of video games in improving health-related outcomes: a systematic review. *Am. J. Prev. Med.* 42, 630–638. doi: 10.1016/j.amepre.2012.02.023

Ramírez-Granizo, I. A., Ubago-Jiménez, J. L., González-Valero, G., Puertas-Molero, P., and San Román-Mata, S. (2020). The effect of physical activity and the use of active video games: exergames in children and adolescents: a systematic review. *Int. J. Environ. Res. Public Health* 17:4243. doi: 10.3390/ijerph17124243

Rebetez, C., and Betrancourt, M. (2007). Video game research in cognitive and educational sciences. *Cogn. Brain Behav.* 11, 131–142.

Reynolds, J. E., Thornton, A. L., Lay, B. S., Braham, R., and Rosenberg, M. (2014). Does movement proficiency impact on exergaming performance? *Hum. Mov. Sci.* 34, 1–11. doi: 10.1016/j.humov.2014.02.007

Ribas, C. G., da Silva, L. A., Corrêa, M. R., Teive, H. G., and Valderramas, S. (2017). Effectiveness of exergaming in improving functional balance, fatigue, and quality of life in Parkinson's disease: a pilot randomized controlled trial. *Parkinsonism Relat. Disord.* 38, 13–18. doi: 10.1016/j.parkreldis.2017.02.006

Richardson, K. (2019). *Models of cognitive development*. London: Psychology Press.

Russell, W. D., and Newton, M. (2008). Short-term psychological effects of interactive video game technology exercise on mood and attention. *Educ. Technol. Soc.* 11, 294–308.

Rüth, M., and Kaspar, K. (2021). Educational and social exergaming: a perspective on physical, social, and educational benefits and pitfalls of exergaming at home during the COVID-19 pandemic and afterwards. *Front. Psychol.* 12:644036. doi: 10.3389/fpsyg.2021.644036

Savickiene, I. (2010). Conception of learning outcomes in the Bloom's taxonomy affective domain. *Qual. High. Educ.* 7, 37–59.

Seaman, M. (2011). "Bloom's taxonomy: its evolution, revision, and use in the field of education" in *Curriculum and teaching dialogue*. eds. D. J. Flinders and P. B. Uhrmacher (Information Age Publishing Inc.), 29–45.

Sheehan, D., and Katz, L. (2010). Using interactive fitness and exergames to develop physical literacy. *Phys. Health Educ.* 76, 12–19.

Solomon, E. (1984). *Games programming*. New York: Cambridge University Press.

Staiano, A. E., and Calvert, S. L. (2011). Exergames for physical education courses: physical, social, and cognitive benefits. *Child Dev. Perspect.* 5, 93–98. doi: 10.1111/j.1750-8606.2011.00162.x

The Exergame Network (2012). Exergaming methods. Available at: http://exergaming.pbworks.com/w/page/12085430/FrontPage (Accessed 30 October 2013).

Vieira, C., da Silva Pais-Vieira, C. F., Novais, J., and Perrotta, A. (2021). Serious game design and clinical improvement in physical rehabilitation: systematic review. *JMIR Serious Games* 9:e20066. doi: 10.2196/20066

Wagener, T. L., Fedele, D. A., Mignogna, M. R., Hester, C. N., and Gillaspy, S. R. (2012). Psychological effects of dance-based group exergaming in obese adolescents. *Pediatr. Obes.* 7, e68–e74. doi: 10.1111/j.2047-6310.2012.00065.x

WHO Consultation on Obesity (2000). Obesity: preventing and managing the global epidemic: report of a WHO consultation. *WHO Tech. Rep. Ser.* 894, 1–253. Available at: https://apps.who.int/iris/handle/10665/42330

World Health Organization (2021). "Obesity and overweight," newsroom, June 9, 2021. Available at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (Accessed 22 May 2023).

Zhao, C., Zhao, C., Zhao, M., Wang, L., Guo, J., Zhang, L., et al. (2022). Effect of exergame training on working memory and executive function in older adults. *Sustainability* 14:10631. doi: 10.3390/su141710631

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The relationship between fundamental motor skills and physical fitness in preschoolers: a short-term longitudinal study

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Purpose: Physical fitness and fundamental motor skills are two important aspects for the healthy development of preschoolers. Despite the growing interest in clarifying their relationship, the scarcity of longitudinal studies prevents us from understanding causality.

Method: This study employed a cross-lagged model with two time points to investigate the bidirectional relationship between these two aspects. A total of 174 preschoolers (54.0% girls) from 3 to 6 years old ($M = 3.96 \pm 0.47$) were surveyed, they were recruited by convenience from two kindergartens in Beijing, China, and their physical fitness (via CNPFDSM-EC) and fundamental motor skills (via TGMD-3) were tracked over a period of 6 months.

Results: The findings revealed a bidirectional predictive effect. The predictive strength of flexibility was found to be lower than other physical fitness aspects, while locomotor skills demonstrated a higher predictive strength than object control skills.

Conclusion: This study indicates that physical fitness and fundamental motor skills mutually enhance each other in young children, and both should be emphasized in preschool sports education.

KEYWORDS

fundamental motor skills, physical fitness, preschoolers, longitudinal data, cross-lagged model

1. Introduction

Fundamental motor skills and physical fitness are crucial factors in fostering positive trajectories of health over time. Fundamental motor skills refer to basic, non-naturally occurring, and learnable movement patterns (Haywood and Getchell, 2014). In early life, mastering a broad range of these skills is beneficial for future learning of more complex motor skills, active and continuous participation in various sports, and the development of a lifelong exercise habit (Henrique et al., 2016). Furthermore, during this developmental period, fundamental motor skills are positively correlated with children's physical activity, healthy weight status, and even their academic performance (Robinson et al., 2015; Engel et al., 2018; de Waal, 2019). Physical fitness refers to an individual's capacity to undertake physical activity. Its components include cardiorespiratory fitness, muscular strength, speed-agility and flexibility (Caspersen et al., 1985), and it is a health and well-being indicator even from a young age (Ortega et al., 2008). Moreover, physical fitness is thought to have a positive effect on a range of psychological indicators, such as cognition, depression, and self-esteem (Cadenas-Sanchez et al., 2021).

Fundamental motor skills and physical fitness are correlated in early childhood (Utesch et al., 2019). The conceptual framework presented by Stodden (2008) explains that the acquisition of motor skill competence in fundamental motor skills in early childhood (2–5 years of age) serves to enhance physical fitness. As the child ages, this relationship evolves into a bidirectional one in mid to late childhood. Similarly, Hulteen et al. (2018) propose a model that delineates the progression of motor skills over time. This model illustrates that skill development can either be hindered or enhanced by physical and psychological factors such as physical fitness and perceived competence. Both models emphasize the importance of understanding the development of fundamental motor skills and physical fitness, as well as their influence on each other.

Although both models hypothesize a relationship between fundamental motor skills and physical fitness during early childhood, the current research evidence is quite limited. This is supported by the results of a meta-analysis, which underscores the lack of studies investigating the relationship between fundamental motor skills and physical fitness in children younger than 7–8 years of age (Utesch et al., 2019). Only two cross-sectional studies have explored the correlation between these two aspects among preschoolers. Frith and Loprinzi (2019) demonstrated a positive correlation between motor skills and musculoskeletal endurance (measured via the plank test), and Wang et al. (2019) supported a low to moderate positive association between fundamental motor skills and physical fitness. However, due to the cross-sectional nature of these studies, it's impossible to determine causality in their co-development. Longitudinal studies provide the potential to uncover their dynamic and reciprocal relationship. This capability will assist researchers and practitioners in understanding how to stimulate and nurture physical fitness and motor competence more effectively. The ultimate goal is to improve health outcomes and promote lifelong physical activity.

Thus, the goal of this study is to employ a longitudinal study design, comprising two time points, to explore the relationship between physical fitness and fundamental motor skills through a cross-lagged model, after controlling for confounding factors such as age, gender and BMI. Our hypothesis is that the relationship between these two aspects at the preschool age is bidirectional and mutually reinforcing.

2. Materials and methods

2.1. Participants

An observational longitudinal design was used to study 174 typically developed children (54.0% girls) from 3 to 6 years old ($M = 3.96 \pm 0.47$) at baseline. Participants were recruited by convenience from two kindergartens in Beijing, China. Data were collected two time points, the baseline test (T1) was conducted from November to December 2020, and the follow-up test (T2) was conducted at a 6-month interval, from May to June 2021. A total of 212 children participated in T1, and 174 participated in T2 (the lower number being a result of absences, illnesses and transfers), with an attrition rate of 17.5%. Analysis of the attrition sample, chi-square and t-test results suggested no significant difference between children who continued to participate in the study and those who did not, in terms of gender ($\chi^2 = 2.71$, $p = 0.23$); age ($t = 0.97$, $p = 0.45$) and aspects of physical fitness and fundamental motor skills ($p > 0.05$). This indicated random attrition. Parents of all participants signed the Parental Informed Consent Form to indicate their consent to participate in the study.

2.2. Instruments

Fundamental motor skills were assessed using the third edition of the Test of Gross Motor Development (TGMD-3), a process-oriented test that contains locomotor and object control subtests (Ulrich, 2019) The former subtest comprised 6 skills: running, horizontal jump, hop, gallop, slide, and skip; and the latter 7: two-handed strike of a stationary ball, forehand strike of self-bounced ball, one hand stationary dribble, overhand throw, underhand throw, two-handed catch, and kicking a stationary ball. Each skill in TGMD-3 was tested twice and scored according to 3 to 5 criteria, with 1 point for meeting one criterion and 0 points for meeting none. The original score was 46 for locomotor skills, 54 for object control motor skills, and 100 for total score. This scale has acceptable internal consistency and test–retest reliability for Chinese children (Ning et al., 2016a; Diao et al., 2018).

Physical fitness was assessed using the early childhood section of the China National Physical Fitness Determination Standard Manual(CNPFDSM-EC), formulated by the State General Administration of Sports (Zhang et al., 2017). The test comprised 6 items: 10-meter shuttle run, horizontal jump, tennis ball throwing, continuous jumping with both feet, sit-and-reach, and balance beam walking. All items were measured twice, and the best score taken. In addition to physical fitness, the height and weight of the preschoolers were measured, and the Body Mass Index (BMI = weight/[height^2]) was calculated. The classification of overweight and obese used in this study is based on the BMI criteria established by the International Obesity Working Group (Cole, 2000).

2.3. Procedure

All tests were conducted in the playgrounds of the respective schools and lasted approximately 30–45 min per child.

Tests of fundamental motor skills were performed by two trained research assistants, one of whom was responsible for demonstrating and testing, and the other for recording the preschoolers' performances using a video camera. The testing protocol began with a single demonstration by the research assistant, followed by one practice trial. If the child's performance during the trial was deemed incorrect, an additional demonstration was provided. Subsequently, two formal tests were administered. After the test, a trained observer assessed the child's performance via video. The observer had a previously established 93% interrater agreement with a trained researcher.

Physical fitness, height and weight tests were administered by three additional trained research assistants. Each assistant had a distinct role: one conducted the tests, another ensured the children's safety, and the third recorded the test results. To ensure both testing efficiency and adherence to the principles of static and dynamic performance during the testing process, a sequence was established: balance beam walking, 10-meter shuttle run, standing long jump, tennis ball throwing, continuous jumping with both feet, sit-and-reach. The final measurements were height and weight.

2.4. Statistical analyses

First, descriptive statistics were obtained for each variable, and the age and gender characteristics of BMI, physical fitness and fundamental motor skills were presented by a two-way analysis of variance (two-way ANOVA), with the changes in the development of each variable over time presented in a paired t-test. Second, to examine the correlation between BMI, physical fitness and fundamental motor skills at two time points, correlation indexes were calculated through Pearson's correlation coefficient. Finally, cross-lagged models were used, controlling for variables such as age, gender and BMI, to further confirm the chronological order and causality between physical fitness and fundamental motor skills.

The two-way ANOVA, paired t-test and correlation analysis were performed in SPSS 18.0, and the cross-lagged model test in Mplus 8.3. The fit index and acceptable critical values used for the cross-lagged model assessment were $\chi2$, df ($\chi2$ / df < 2), CFI (> 0.90), TLI (> 0.90), RMSEA (< 0.08), and SRMR (< 0.08), respectively, as used in previous studies (Hu and Bentler, 1999).

3. Results

3.1. Descriptive data and correlations

Before examining the cross-lagged model, we tested the descriptive data and correlation matrix. The results of the two-way ANOVA showed that the main effects of age and gender were significant in both T1 and T2, but there was no interaction between the variables (see Table 1). For this reason, only the separate effects of age and gender will be analyzed.

At T1, the main effects of age on BMI and sit-and-reach were not significant, while the remaining indicators of physical fitness and fundamental motor skills had a significant main effect and increased with age. The main effect of gender was significant only in tennis ball throwing and object control skills, where boys scored significantly higher ($F = 23.121$, $p < 0.001$, $\eta_p^2 = 0.171$; and $F = 11.181$, $p < 0.001$, $\eta_p^2 = 0.134$ respectively) (see Table 2). At T2, the main effects of age on BMI and object control skills were not significant, the remaining indicators also increased with age, with a significant main effect. The main effect of gender was significant only in tennis ball throwing, object control skills and sit-and-reach. In the former two, boys scored significantly higher ($F = 16.690$, $p < 0.001$, $\eta_p^2 = 0.152$; and $F = 16.064$, $p < 0.001$, $\eta_p^2 = 0.147$ respectively), but had lower scores in sit-and-reach ($F = 11.181$, $p = 0.001$, $\eta_p^2 = 0.134$) (see Table 3). The 6-month follow-up data suggested that the BMI of participants did not change over time ($t = 1.109$, $p = 0.270$), while the other indicators improved significantly (see Table 4).

TABLE 1 Main effects and interaction analysis of age and gender.

Time point	Age		Gender		Age*Gender	
	F	*p*	*F*	*p*	*F*	*p*
T1	7.762	< 0.001	3.297	0.001	1.629	0.113
T2	4.276	< 0.001	4.226	< 0.001	0.985	0.470

T1 is the time point of the baseline test; T2 is the time point of the follow-up test, 6 months later.

As can be seen from the results of the correlation matrix, BMI was not significantly correlated with either fundamental motor skills or physical fitness. The correlation between sit-and-reach and fundamental motor skills was weak, and the rest of the physical fitness were significantly correlated with fundamental motor skills (see Table 5).

3.2. Cross-lagged model results

On the basis of the correlation analysis, the cross-lagged model was used to explore the longitudinal relationship between physical fitness and fundamental motor skills. The results showed that age and gender had significant effects on both, while BMI did not. As a result, only age and gender were included as control variables in the model. The model had a good degree of fit: $\chi^2 = 120.73$, df = 84, $\chi2$/df = 1.44, $p > 0.05$, RMSEA = 0.067, CFI = 0.951, TLI = 0.931, SRMR = 0.049.

Figure 1 showed that T1 physical fitness effectively predicted T2 physical fitness ($\beta = 0.74$, SE = 0.086, $p < 0.001$), and similarly, T1 fundamental motor skills effectively predicted T2 fundamental motor skills ($\beta = 0.43$, SE = 0.212, $p = 0.043$), In terms of the β coefficient, physical fitness has greater stability compared to fundamental motor skills. After controlling for the effects of age, gender, and autoregressive effects, T1 fundamental motor skills effectively predicted T2 physical fitness ($\beta = 0.20$, SE = 0.094, $p = 0.034$). Among the two dimensions of fundamental motor skills, the factor loadings for locomotor skills were higher than those for object control skills. Furthermore, T1 physical fitness also effectively predicted T2 fundamental motor skills ($\beta = 0.50$, SE = 0.212, $p = 0.017$). In physical fitness, the factor loadings of sit-and-reach were lower than those of the other dimensions.

4. Discussion

This study used a cross-lagged model to investigate the bidirectional relationship between physical fitness and fundamental motor skills in preschoolers. In doing so, it compensated for the shortcomings of previous cross-sectional studies that could determine the magnitude but not the direction of the association, and provided new evidence for the relationship. The findings support our proposed research hypothesis that preschoolers' fundamental motor skill levels could predict physical fitness (and vice versa) 6 months later.

To control the extraneous variables in the subsequent cross-lagged model, this study first examined the demographic variables of age, gender, and BMI. The results showed that age and gender had a significant effect on physical fitness and fundamental motor skills, while BMI did not. When cross-sectional and longitudinal data were combined, all indicators except BMI increased with age, which is consistent with previous studies (Yang et al., 2015; Ning et al., 2016b; Tu et al., 2021), and with the growth and development patterns of preschoolers. Boys outperformed girls in both object control skills and tennis ball throwing, whereas girls excelled in sit-and-reach. The

TABLE 2 Descriptive statistics at T1.

Indicator	Age 3.5		Age 4.5		p	
	Boys (n = 40)	Girls (n = 48)	Boys (n = 40)	Girls (n = 46)	Age	Gender
BMI (kg/m^2)	16.4 ± 1.26	15.7 ± 1.17	15.8 ± 1.22	15.8 ± 1.80	0.540	0.306
Overweight (n, %)	2, 1.15%	3, 1.72%	0	1, 0.57%	–	–
Obese (n, %)	2, 1.15%	1, 0.57%	0	0	–	–
Physical fitness						
Horizontal jump (cm)	68.1 ± 15.33	70.9 ± 14.24	86.3 ± 21.14	83.3 ± 18.84	**< 0.001**	0.983
Tennis ball throwing (m)	3.8 ± 1.52	2.9 ± 0.67	4.9 ± 1.84	3.6 ± 0.87	**0.003**	**< 0.001**
Sit-and-reach (cm)	8.9 ± 2.99	11.9 ± 3.74	10.2 ± 4.11	10.2 ± 4.60	0.802	0.112
10-meter shuttle run (s)	9.1 ± 1.26	9.3 ± 1.21	7.5 ± 0.77	7.7 ± 0.72	**< 0.001**	0.272
Balance beam walking (s)	21.2 ± 13.63	14.5 ± 7.13	7.2 ± 4.14	9.4 ± 4.38	**< 0.001**	0.234
Continuous jumping with both feet (s)	7.3 ± 2.70	7.8 ± 3.77	7.1 ± 2.62	5.9 ± 1.21	0.099	0.593
FMS						
Locomotor skills	17.3 ± 8.24	20.6 ± 6.59	27.4 ± 6.29	27.7 ± 5.65	**< 0.001**	0.245
Object control skills	19.6 ± 4.01	15.7 ± 4.59	21.6 ± 5.03	18.9 ± 3.54	**0.012**	**0.001**
Total FMS score	36.9 ± 10.05	36.4 ± 7.85	49.1 ± 10.47	46.6 ± 7.75	**< 0.001**	0.471

The bold values represent that p - values are statistically significant.

TABLE 3 Descriptive statistics at T2.

Indicator	Age 4.0		Age 5.0		p	
	Boys (n = 40)	Girls (n = 48)	Boys (n = 40)	Girls (n = 46)	Age	Gender
BMI (kg/m^2)	15.7 ± 1.40	15.7 ± 1.11	15.9 ± 1.44	15.5 ± 1.61	0.869	0.464
Overweight (n, %)	1, 0.57%	1, 0.57%	1, 0.57%	1, 0.57%	–	–
Obese (n, %)	4, 2.30%	1, 0.57%	0	0	–	–
Physical fitness						
Horizontal jump (cm)	93.6 ± 13.14	87.8 ± 15.78	104.3 ± 15.01	105.8 ± 13.20	**< 0.001**	0.470
Tennis ball throwing (m)	5.1 ± 1.30	4.1 ± 0.94	6.3 ± 1.43	5.3 ± 1.21	**< 0.001**	**< 0.001**
sit-and-reach (cm)	13.2 ± 3.78	16.8 ± 2.99	12.0 ± 4.32	14.2 ± 3.12	**0.010**	**< 0.001**
10-meter shuttle run (s)	7.4 ± 0.54	7.5 ± 0.80	6.7 ± 0.62	6.9 ± 0.30	**< 0.001**	0.250
Balance beam walking (s)	8.1 ± 4.43	8.2 ± 3.91	6.7 ± 4.31	6.0 ± 1.79	**0.021**	0.690
Continuous jumping with both feet (s)	6.9 ± 1.26	7.2 ± 1.81	6.2 ± 1.20	6.0 ± 0.63	**< 0.001**	0.837
FMS						
Locomotor skills	24.2 ± 6.48	26.6 ± 6.33	27.9 ± 5.35	28.3 ± 5.19	**0.027**	0.240
Object control skills	20.6 ± 5.64	18.2 ± 7.35	24.4 ± 8.06	19.7 ± 5.51	0.058	**0.010**
Total FMS score	44.8 ± 10.46	44.8 ± 10.59	52.3 ± 11.62	47.7 ± 8.23	**0.014**	0.276

The bold values represent that p - values are statistically significant.

TGMD-3 also found gender differences in fundamental motor skills when establishing regional norms in the United States (Ulrich, 2019) and Shanghai, China (Diao et al., 2018), thereby setting separate object control skill norms for boys and girls. Previous studies suggest that such gender differences are not biological (Goodway et al., 2021) but are associated with family, environmental, and sociocultural factors (Krombholz, 2006; Spessato et al., 2012; Iivonen and Sääkslahti, 2014). For example: parents tend to encourage boys to participate in ball games, and girls in sports related to gymnastics, dance, or role-play. As a result, boys and girls have different sporting experiences that cause them to perform differently in tennis ball throwing and sit-and-reach. The analysis in this study revealed no association between BMI and either physical fitness or fundamental motor skills. This contradicts previous studies that found a negative relationship

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TABLE 4 Changes between T1 and T2 data.

	T1	T2	Variation	95%CI	*p*
Body shape					
Height (cm)	105.0 ± 4.54	109.3 ± 4.79	4.2 ± 4.21	(3.4, 5.1)	**<0.001**
Weight (kg)	17.5 ± 2.46	18.8 ± 2.65	1.3 ± 2.25	(0.9, 1.8)	**<0.001**
BMI (kg/m^2)	15.8 ± 1.41	15.7 ± 1.39	−0.1 ± 1.24	(−0.4, 0.1)	0.270
Physical fitness					
Horizontal jump (cm)	72.1 ± 21.81	98.3 ± 16.11	26.2 ± 20.34	(22.0, 34.0)	**<0.001**
Tennis ball throwing (m)	3.5 ± 1.36	5.2 ± 1.44	1.7 ± 1.72	(1.3, 2.0)	**<0.001**
Sit-and-reach (cm)	10.1 ± 3.92	14.1 ± 3.90	4.0 ± 4.69	(3.0, 4.9)	**<0.001**
10-meter shuttle run (s)	8.7 ± 1.44	7.1 ± 0.66	−1.6 ± 1.31	(−1.8, −1.3)	**<0.001**
Balance beam walking (s)	13.4 ± 9.11	7.3 ± 4.24	−6.1 ± 8.04	(−7.8, −4.4)	**<0.001**
Continuous jumping with both feet (s)	7.7 ± 3.37	6.6 ± 1.80	−1.1 ± 3.26	(−1.8, −0.4)	**0.002**
FMS					
Locomotor skills	22.6 ± 7.81	26.8 ± 5.99	4.1 ± 8.63	(2.4, 5.9)	**<0.001**
Object control skills	17.8 ± 5.24	20.6 ± 6.91	2.8 ± 7.27	(1.3, 4.3)	**<0.001**
Total FMS score	40.4 ± 11.17	47.3 ± 10.43	6.9 ± 12.61	(4.4, 9.4)	**<0.001**

The bold values represent that *p* - values are statistically significant.

between BMI and fundamental motor skills, particularly locomotor skills (Southall et al., 2004; Zhou, 2020). This is because preschoolers need to overcome gravity to coordinate their body movements; overweight and obese children find this more challenging, resulting in lower locomotor skills scores. A Chinese study that investigated the effect of weight on the physical fitness of children aged 5–6 found that the group with normal body weight had a higher level of physical fitness than the under-and overweight groups (Xu et al., 2015). The small number of overweight and obese children in this study's sample (only 5%) may explain why BMI did not correlate with other indicators.

The cross-lagged results for fundamental motor skills and physical fitness in preschoolers revealed that T1 fundamental motor skills effectively predicted T2 physical fitness. This aligns with several previous longitudinal studies, which found that proficient fundamental motor skills in early childhood had a positive effect on future physical development, including cardiopulmonary endurance, and muscle endurance and strength (Hands, 2008; Fransen et al., 2014; Vlahov et al., 2014; Lima et al., 2019). Fransen et al. (2014) investigated fundamental motor skills, physical fitness and participation in physical activity among 6-year-olds in a two-year follow-up study, and found that children with low levels of movement rarely participated in physical activities. This resulted in a lack of opportunity to develop their fundamental motor skills and physical fitness, which in turn prevented them from catching up with their more active peers. Most of the studies discussed primarily examined the effects of locomotor and stability skills on physical fitness. Our study found further proof of the important role of object control skills in the development of physical fitness. Although the factor loadings for object control skills (0.59) were lower than those for locomotor skills (0.79), this might be related to the composition of the physical fitness test items and the short follow-up period. It does not imply that object control skills are less important than locomotor skills. Vlahov et al. (2014) found in their 11-year follow-up study that object control skills in preschoolers were more predictive of physical fitness in high school than locomotor skills. Despite our study's shorter follow-up period (6 months), it provides evidence that fundamental motor skills are equally predictive of physical fitness in the short term.

The study also discovered that T1 physical fitness effectively predicted T2 fundamental motor skills, which does not support Stodden's hypothesis of a unidirectional relationship between physical fitness and fundamental motor skills in early childhood (Stodden, 2008). Two longitudinal studies also found that the performance of 6-year-old children in grip, horizontal jump, and the 1-mile walk could predict fundamental motor skills at age 9 (dos Santos et al., 2018; Henrique et al., 2018). Wang et al. (2019) demonstrated that physical fitness explained 15–16 percent of motor skill variance. All these studies provide evidence of a bidirectional relationship between fundamental motor skills and physical fitness. Among the six physical fitness in this study, the factor loadings for flexibility, measured by sit-and-reach, were substantially lower than those of other fitness. This result aligns with previous studies, Coppens et al. (2019) found that flexibility in 8-year-old children did not predict fundamental motor skill levels two years later. Although flexibility is structurally less correlated with motor skills from a theoretical perspective, its actual impact needs to be confirmed by further studies, as current research is limited. Cattuzzo et al. (2016) highlighted that the interrelationship between fundamental motor skills and physical fitness is closely related, as both require substantial neuromuscular control to achieve efficient and coordinated motor performance. Furthermore, the two are related both directly, through neuromuscular function, and indirectly, through participation in physical activities. Therefore, Fundamental motor skills and physical fitness mutually enhance each other in early childhood, and both should be the focus of sports promotion in preschools.

4.1. Research limitations and prospects

This study contained some limitations that should be addressed in future research. Firstly, it utilized a limited number of variables; similar

TABLE 5 Correlation analysis at T1 and T2.

		T1				T2			
		BMI	Locomotor	Object control	Total FMS	BMI	Locomotor	Object control	Total FMS
T1	BMI	1	−0.19	−0.13	−0.20	0.59***	0.07	0.13	0.13
	Horizontal jump	−0.10	0.42***	0.06	0.34**	0.04	0.20	0.11	0.20
	Tennis ball throwing	0.05	0.27*	0.41***	0.39**	0.17	0.09	0.34**	0.28*
	Sit-and-reach	−0.07	0.13	0.04	0.12	−0.05	−0.01	−0.04	−0.03
	10-meter shuttle run	0.01	−0.54***	−0.34**	−0.56***	0.03	−0.23*	−0.38**	−0.39**
	Balance beam walking	0.14	−0.37**	−0.05	−0.30**	0.18	−0.33**	−0.16	−0.30**
	Continuous jumping with both feet	0.07	−0.35**	−0.16	−0.33**	0.01	−0.14	−0.2	−0.21
T2	BMI	0.59***	0.01	0.01	0.01	1	−0.02	0.04	0.00
	Horizontal jump	−0.08	0.37**	0.19	0.36**	−0.15	0.47***	0.33**	0.49***
	Tennis ball throwing	−0.11	0.38**	0.17	0.36**	−0.11	0.32**	0.30**	0.39***
	Sit-and-reach	−0.12	0.04	−0.13	−0.03	−0.07	−0.15	−0.23*	−0.24*
	10-meter shuttle run	0.14	−0.38**	−0.27*	−0.41***	−0.03	−0.39***	−0.24*	−0.39**
	Balance beam walking	0.20	−0.24*	0.01	−0.18	0.16	−0.28*	−0.13	−0.24*
	Continuous jumping with both feet	0.04	−0.22	−0.22	−0.27*	0.07	−0.35**	−0.28*	−0.39**

* for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$.

studies usually include a cardiorespiratory test, such as the 20-meter shuttle run, when measuring physical fitness in preschoolers. Additionally, fundamental motor skills include stability skills in addition to locomotor and object control (Barnett et al., 2016). Future studies are recommended to include more variables to explore the role of stability skills and their impact on physical fitness. In addition, sample size is considered important in longitudinal studies. To ensure acceptable attrition rates and account for the rapid growth and development during preschool years, this study used a six-month follow-up interval. However, it was not determined whether this interval was optimal for observing the developmental patterns of both variables. To more comprehensively reveal the developmental trends of the variables and the patterns of the relationships between them, future studies could obtain more accurate relationships between the development of physical fitness and fundamental motor skills in preschoolers by expanding the sample size and extending the duration and number of follow-ups.

4.2. Practical applications

Educators should take a balanced view when evaluating the role of fundamental motor skills in pre-school physical education. This study indicates a bidirectional predictive relationship between fundamental motor skills and physical fitness; in fact, physical fitness plays an even stronger predictive role in the development of fundamental motor skills. This two-way relationship contrasts with older perspectives, notably the Stodden's theoretical model, which posited fundamental motor skills as the sole basis for physical fitness in preschoolers. Relying solely on such a model can result in an imbalanced curriculum that overemphasizes motor skills, hindering well-rounded development in young children.

Moreover, educators should continuously expand their understanding of both fundamental motor skills and physical fitness for preschoolers. Initial surveys from this study revealed that kindergarten teachers in China often have a narrow view, associating fundamental motor skills mainly with actions like "walking, running, jumping, throwing, crawling, climbing, and scaling." This focus predominantly on locomotor skills overlooks the comprehensive framework of fundamental motor skills, which includes three key dimensions: locomotor, object control, and stability (Barnett et al., 2016). Additionally, in terms of physical fitness, strength, speed, and endurance should not be the focus for preschoolers who lack the necessary physical foundation; instead,

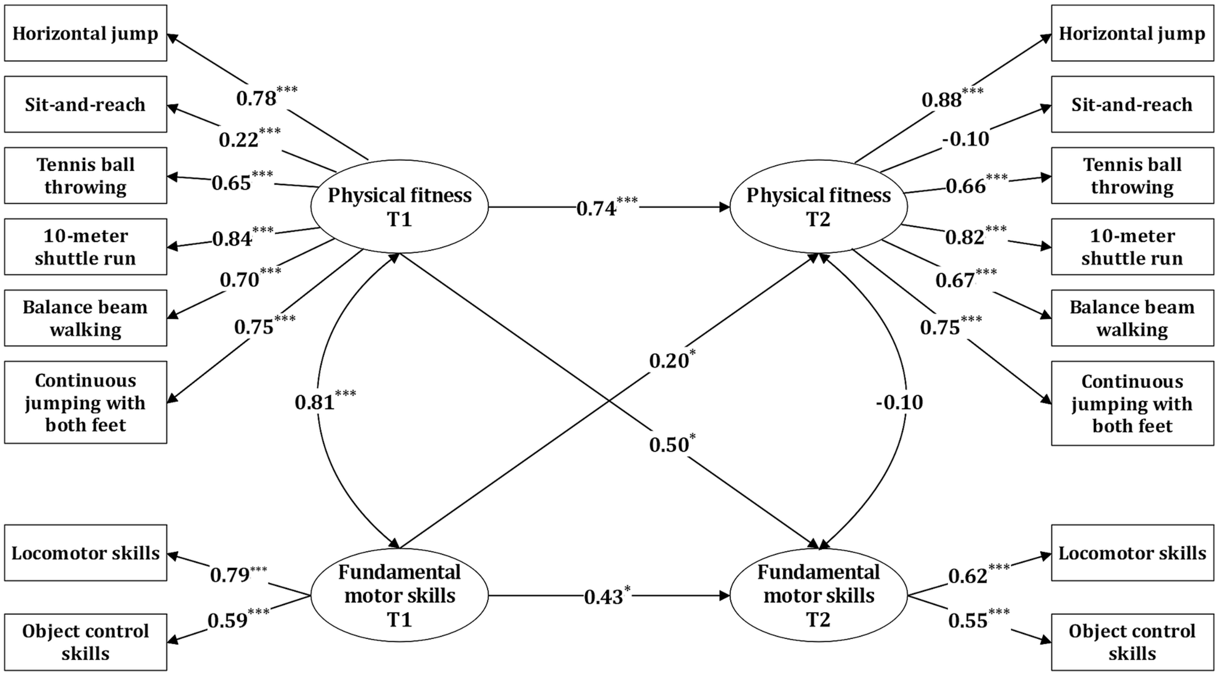

FIGURE 1
Cross-lagged model results for physical fitness and fundamental motor skills.

attributes related to rapid neurological development such as agility, balance, and coordination should be emphasized (Istvan et al., 2013).

5. Conclusion

Physical fitness and fundamental motor skills have been found to exhibit a bidirectional predictive effect in preschoolers. Flexibility, compared to other forms of physical fitness, shows a weaker prediction, while locomotor skills predict more effectively than object control skills. This study provides new evidence for Stodden's theoretical model, and underscoring the importance of simultaneous learning of physical fitness and fundamental motor skills during preschool years to foster the health and development of young children.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Ethics Committee of Nantong University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

JC: Writing – original draft. WS: Writing – review & editing, Methodology. XZ: Writing – review & editing. HL: Writing – review & editing. DL: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Barnett, L. M., Stodden, D., Cohen, K. E., Smith, J. J., Lubans, D. R., Lenoir, M., et al. (2016). Fundamental movement skills: an important focus. *J. Teach. Phys. Educ.* 35, 219–225. doi: 10.1123/jtpe.2014-0209

Cadenas-Sanchez, C., Mena-Molina, A., Torres-Lopez, L. V., Migueles, J. H., Rodriguez-Ayllon, M., Lubans, D. R., et al. (2021). Healthier minds in fitter bodies: a systematic review and Meta-analysis of the association between physical fitness and mental health in youth. *Sports Med.* 51, 2571–2605. doi: 10.1007/s40279-021-01520-y

Caspersen, C. J., Powell, K. E., and Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* 100, 126–131. doi: 10.2307/20056429

Cattuzzo, M. T., Henrique, R. D., Re, A. H. N., de Oliveira, I. S., Melo, B. M., Moura, M. D., et al. (2016). Motor competence and health related physical fitness in youth: a systematic review. *J. Sci. Med. Sport* 19, 123–129. doi: 10.1016/j.jsams.2014.12.004

Cole, T. J. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 320, 1240–1243. doi: 10.1136/bmj.320.7244.1240

Coppens, E., Bardid, F., Deconinck, F. J. A., Haerens, L., Stodden, D., D'Hondt, E., et al. (2019). Developmental change in motor competence: a latent growth curve analysis. *Front. Physiol.* 10, 1–10. doi: 10.3389/fphys.2019.01273

de Waal, E. (2019). Fundamental movement skills and academic performance of 5-to 6-year-old preschoolers. *Early Childhood Educ. J.* 47, 455–464. doi: 10.1007/s10643-019-00936-6

Diao, Y. C., Dong, C. X., and Li, J. (2018). The establishment of norm of gross motor development test in Shanghai. *China Sport Sci. Technol.* 54, 98–104. doi: 10.16470/j.csst.201802013

dos Santos, M. A. M., Nevill, A. M., Buranarugsa, R., Pereira, S., Gomes, T., Reyes, A., et al. (2018). Modeling children's development in gross motor coordination reveals key modifiable determinants. An allometric approach. *Scand. J. Med. Sci. Sports* 28, 1594–1603. doi: 10.1111/sms.13061

Engel, A. C., Broderick, C. R., van Doorn, N., Hardy, L. L., and Parmenter, B. J. (2018). Exploring the relationship between fundamental motor skill interventions and physical activity levels in children: a systematic review and Meta-analysis. *Sports Med.* 48, 1845–1857. doi: 10.1007/s40279-018-0923-3

Fransen, J., Deprez, D., Pion, J., Tallir, I. B., D'Hondt, E., Vaeyens, R., et al. (2014). Changes in physical fitness and sports participation among children with different levels of motor competence: a 2-year longitudinal study. *Pediatr. Exerc. Sci.* 26, 11–21. doi: 10.1123/pes.2013-0005

Frith, E., and Loprinzi, P. D. (2019). Association between motor skills and musculoskeletal physical fitness among preschoolers. *Matern. Child Health J.* 23, 1003–1007. doi: 10.1007/s10995-019-02753-0

Goodway, J. D., Gallahue, D. L., and Ozmun, J. C. (2021). *Understanding motor development: Infants, children, adolescents, adults*. Burlington: Jones & Bartlett Learning.

Hands, B. (2008). Changes in motor skill and fitness measures among children with high and low motor competence: a five-year longitudinal study. *J. Sci. Med. Sport* 11, 155–162. doi: 10.1016/j.jsams.2007.02.012

Haywood, K. M., and Getchell, N. (2014). *Life span motor development*. United States: Huamn Kinetics.

Henrique, R. S., Bustamante, A. V., Freitas, D. L., Tani, G., Katzmarzyk, P. T., and Maia, J. A. (2018). Tracking of gross motor coordination in Portuguese children. *J. Sports Sci.* 36, 220–228. doi: 10.1080/02640414.2017.1297534

Henrique, R. S., Re, A. H. N., Stodden, D. F., Fransen, J., Campos, C. M. C., Queiroz, D. R., et al. (2016). Association between sports participation, motor competence and weight status: a longitudinal study. *J. Sci. Med. Sport* 19, 825–829. doi: 10.1016/j.jsams.2015.12.512

Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct. Equ. Model.* 6, 1–55. doi: 10.1080/10705519909540118

Hulteen, R. M., Morgan, P. J., Barnett, L. M., Stodden, D. F., and Lubans, D. R. (2018). Development of foundational movement skills: a conceptual model for physical activity across the lifespan. *Sports Med.* 48, 1533–1540. doi: 10.1007/s40279-018-0892-6

Iivonen, S., and Sääkslahti, A. K. (2014). Preschool children's fundamental motor skills: a review of significant determinants. *Early Child Dev. Care* 184, 1107–1126. doi: 10.1080/03004430.2013.837897

Istvan, B., Colin, H., and Richard, W. (2013). *Long-term athlete development*. Champaign, IL: Human Kinetics.

Krombholz, H. (2006). Physical performance in relation to age, sex, birth order, social class, and sports activities of preschool children. *Percept. Mot. Skills* 102, 477–484. doi: 10.2466/pms.102.2.477-484

Lima, R. A., Bugge, A., Ersboll, A. K., Stodden, D. F., and Andersen, L. B. (2019). The longitudinal relationship between motor competence and measures of fatness and fitness from childhood into adolescence. *J. Pediatr.* 95, 482–488. doi: 10.1016/j.jped.2018.02.010

Ning, K., Shen, X. S., and Shao, X. J. (2016a). The relationship between locomotor development and perceived physical competence in children aged 3-6 years: an empirical study. *J. Beijing Sport Univ.* 39, 74–81. doi: 10.19582/j.cnki.11-3785/g8.2016.12.012

Ning, K., Shen, X. S., and Shao, X. J. (2016b). Research on the age and gender characteristics of the development of gross motor in preschool children. *Chinese J. Child Health Care* 24, 1322–1325. doi: 10.11852/zgetbjzz2016-24-12-27

Ortega, F. B., Ruiz, J. R., Castillo, M. J., and Sjostrom, M. (2008). Physical fitness in childhood and adolescence: a powerful marker of health. *Int. J. Obes.* 32, 1–11. doi: 10.1038/sj.ijo.0803774

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., et al. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Med.* 45, 1273–1284. doi: 10.1007/s40279-015-0351-6

Southall, J. E., Okely, A. D., and Steele, J. R. (2004). Actual and perceived physical competence in overweight and nonoverweight children. *Pediatr. Exerc. Sci.* 16, 15–24. doi: 10.1123/pes.16.1.15

Spessato, B., Gabbard, C., Valentini, N., and Rudisill, M. (2012). Gender differences in Brazilian Children's fundamental movement skill development. *Early Child Dev. Care* 183, 916–923. doi: 10.1080/03004430.2012.689761

Stodden, D. F. (2008). A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest* 60, 290–306. doi: 10.1080/07303084.2007.10598077

Tu, C. J., Zhang, Y. F., Wu, D. M., Zhang, S. H., and Jiang, C. M. (2021). Construction BMI percentile standard curve and cut-off points for overweight and obesity of 3~6 years children based on GAMLSS model in China. *China Sport Sci.* 41, 63–73. doi: 10.16469/j.css.202103008

Ulrich, D. A. (2019). *The test of gross motor development-3 (tgmd-3): Examiner's manual*. Austin: Pro-ed.

Utesch, T., Bardid, F., Busch, D., and Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: a Meta-analysis. *Sports Med.* 49, 541–551. doi: 10.1007/s40279-019-01068-y

Vlahov, E., Baghurst, T. M., and Mwavita, M. (2014). Preschool motor development predicting high school health-related physical fitness: a prospective study. *Percept. Mot. Skills* 119, 279–291. doi: 10.2466/10.25.PMS.119c16z8

Wang, H., Hu, S. Q., Li, Y. C., and Zheng, Y. D. (2019). Canonical correlation of motor skills and physical fitness in preschool children. *China Sport Sci. Technol.* 55, 46–51. doi: 10.16470/j.csst.2019018

Xu, L. L., Liu, X., and Wang, M. (2015). Effect of underweight and overweight on children's physical fitness. *China Sport Sci. Technol.* 51, 127–131. doi: 10.16470/j.csst.2015.01.015

Yang, S.-C., Lin, S.-J., and Tsai, C.-Y. (2015). Effect of sex, age, and bmi on the development of locomotor skills and object control skills among preschool children. *Percept. Mot. Skills* 121, 873–888. doi: 10.2466/10.PMS.121c29x0

Zhang, Y. H., He, Z. T., and Xu, J. H. (2017). *National Physical Fitness Surveillance and evaluation*. BeiJing: Science Press.

Zhou, Z. X. (2020). Research on the characteristics of preschoolers physical fitness and BMI under the vision of multi-level motor. *China Sport Sci. Technol.* 56, 62–68. doi: 10.16470/j.csst.2019174

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Effect of an activity wristband-based intermittent teaching unit in Physical Education on students' physical activity and its psychological mediators: a cluster-randomized controlled trial. School-fit study

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Objective: The main objective of the present study was to examine the effects of an intermittent teaching unit based on the use of activity wristbands and behavior modification strategies on high school students' perceptions of autonomy support, satisfaction of basic psychological needs, motivation toward Physical Education and physical activity, intention to be physically active, and habitual physical activity levels.

Materials and methods: An initial sample of 353 high school students (final sample = 175; 45.7% females; mean age = 13.3 ± 1.2 years) from two public high schools were cluster-randomly assigned into the intermittent (IG, $n = 100$) and control (CG, $n = 75$) groups. The IG performed an intermittent teaching unit twice a week for eight weeks. Specifically, the last 15 min of each lesson were used. As the main strategy to promote the practice of regular physical activity, students wore an activity wristband the whole day during the intervention period. Additionally, other behavior modification strategies were also applied (e.g., educational counseling, physical activity goals or reminders). Regarding the CG, during the intervention period (i.e,, the eight weeks that took place the intermittent teaching unit) they also performed two Physical Education sessions, but without using activity wristbands or other behavior modification strategies. Before and after the intervention, as well as at the end of the follow-up period (six weeks), students' physical activity practice mediators and physical activity levels were measured by validated questionnaires.

Results: The Multilevel Linear Model results showed that the IG students statistically significantly improved cognitive and procedural autonomy support from pre- to post-intervention ($p < 0.05$). They also statistically significantly improved autonomy and relatedness basic psychological needs, and autonomous motivation toward physical activity scores from post-intervention to follow-up ($p < 0.05$). Moreover, the results showed that the IG students statistically significantly improved habitual physical activity scores from pre- to post-intervention, and from post-intervention to follow-up ($p < 0.05$).

Conclusion: The intermittent teaching unit based on the use of activity wristbands and other behavior modification strategies was effective for improving students' autonomy support and habitual physical activity levels, but not the rest of physical activity practice mediators.

Clinical trial registration: https://register.clinicaltrials.gov/, ID: NCT05949463.

KEYWORDS

innovative program, wrist-worn wearables, autonomy support, motivation, physical activity levels, trans-contextual model, high school students

1. Introduction

Health benefits of regular physical activity (PA) in adolescents are well known (World Health Organization, 2020). The World Health Organization (2020) recommends that adolescents should do at least an average of 60 min per day of moderate-to-vigorous PA (MVPA) across the week. However, worldwide more than 80% of adolescents do not meet this recommendation (Guthold et al., 2020). Therefore, the promotion of adequate PA levels among adolescents is an important public health priority, which can take place in different settings of daily life (World Health Organization, 2018). Among others, the Physical Education (PE) subject plays an essential role in adolescents' PA promotion (Association for Physical Education, 2020; World Health Organization, 2020), because it has been shown to have positive effects on their PA levels at school (Mayorga-Vega et al., 2018). Also, it provides adolescents with health literacy skills that empower them to be physically active outside school (Slingerland and Borghouts, 2011).

Although one of the main PE national standards worldwide is the promotion of students' lifelong PA (European Commission/EACEA/Eurydice, 2013; SHAPE America, 2013), there are several limitations that make difficult its achievement (Casado-Robles et al., 2019). For example, the large volume of curricular objectives and contents that have to be developed in a fairly limited time (Casado-Robles et al., 2019) or the difficulty of controlling students' PA outside school (Casado-Robles et al., 2019). A feasible solution could be promoting PA practice through the application of the intermittent teaching unit structure proposed by Viciana and Mayorga-Vega (2016). Intermittent teaching units are defined as those teaching units given in small temporary periods during all the lessons of the course or of a specific period (Viciana and Mayorga-Vega, 2016). For instance, this innovative structure of the teaching unit could consist of only a few minutes of each PE lesson (e.g., the last 15 min) for several lessons. Thus, it allows for dividing the lesson into several parts (i.e., two) and developing two or more related curricular objectives during the same lesson. This could provide teachers a more efficient use of the limited PE time developing various goals during the lessons, and students the opportunity to establish relationships between different PE-related contents. Previous empirical studies have shown the effectiveness of this teaching unit structure in developing and maintaining different health-related physical fitness curricular objectives over time, such as cardiorespiratory fitness or strength (Mayorga-Vega et al., 2016; Guijarro-Romero et al., 2020). Nevertheless, to date it has not been applied for promoting students' PA practice.

Additionally, even though PE is potentially considered a key context to promote students' PA (Association for Physical Education, 2020; World Health Organization, 2020), most PE-based interventions seem to show small or non-significant effects on increasing students' PA levels (Borde et al., 2017; Love et al., 2019). Furthermore, Nguyen et al. (2016) observed that intervention effects diminish over the time, which may compromise long-term effectiveness of PA promotion interventions. The lack of theoretical behavior change frameworks in the design of school-based interventions could be the cause of these small effect sizes (Borde et al., 2017; Rhodes et al., 2017). Therefore, applying PE-based PA interventions, specifically grounded in theoretical frameworks of behavior change, could help to enhance motivational outcomes in PE and leisure-time PA context, as well as to maintain the beneficial effects of an intervention over time (Kwasnicka et al., 2016; Rhodes et al., 2017).

The Self-Determination Theory (SDT) is a motivational theory widely used to understand the antecedents and consequences of students' motivation toward PA both in the school context of PE and in the out-of-school context (Deci and Ryan, 1985; Ryan and Deci, 2020). The SDT considers motivation as a multidimensional construct with different levels along a *continuum* according to the degree of autonomy, ranging from more self-determined (i.e., autonomous) to less self-determined (i.e., controlled) forms of behavioral regulations (Ryan and Deci, 2020). Autonomous forms of motivation include intrinsic motivation, as well as integrated, and identified regulation (Ryan et al., 2021). Intrinsic motivation is related to the inherent pleasure and satisfaction provided by an activity; integrated regulation refers when activity is completely assimilated with individual's sense of self; and identified regulation refers when an activity is aligned with personal values (Ryan and Deci, 2020). Controlled forms of motivation comprise introjected (i.e., acting to avoid sense of guilt or anxiety or to protect contingent self-worth) and external (i.e., doing an activity for contingent rewards or avoid punishments) regulations (Ryan and Deci, 2020; Ryan et al., 2021). Finally, amotivation is characterized by no intention of an individual to act due to different reasons such as lack of certain skills or knowledge necessary to act (Ryan and Deci, 2020). The SDT postulates

Abbreviations: PA, Physical activity; MVPA, Moderate-to-vigorous physical activity; PE, Physical Education; SDT, Self-Determination Theory; TCM, trans-contextual model; IG, intermittent group; CG, control group; MD-PASS-PA, Multi-Dimensional Perceived Autonomy Support Scale for Physical Education; BPNES, Basic Psychological Needs in Exercise Scale; PLOC-R, Revised Perceived Locus of Causality Scale; BREQ-3, Behavioral Regulation in Exercise Questionnaire; PACE, Physician-based Assessment and Counseling for Exercise; ANOVA, one-way analyses of variance; ANCOVA, one-way analyses of covariance.

that everyone has three basic psychological needs: autonomy, which refers to the need for initiative and ownership in one's own behavior; competence, which refers to the need to feel capable of performing a behavior effectively, and relatedness, which refers to the need of belonging and connection by significant others (Ryan and Deci, 2020). Satisfaction of these three basic psychological needs, leads students to acquire more autonomous forms of motivation toward PA (Ryan and Deci, 2020). Furthermore, according to the SDT the autonomy support of PE teachers in PE plays a key role in the development of a more autonomous motivation toward PA (Ryan and Deci, 2020), which is positively associated with the interest in remaining active in the out-of-school time (Sevil-Serrano et al., 2022). The autonomy-supportive teaching style is characterized by making students feel that they can participate in their own learning (Ryan and Deci, 2020). In this sense, Stefanou et al. (2004) proposed that autonomy support could be characterized by three clearly different dimensions: organizational (i.e., autonomy in terms of encouraging students' ownership of decisions in relation to PA), procedural (i.e., autonomy in terms of encouraging students' to conduct the teaching-learning process), and cognitive (i.e,, autonomy in terms of promoting students' ownership to express and argue their particular viewpoint in the teaching-learning process). According to SDT framework, the application of an autonomy-supportive teaching style and the improvement of students' autonomous motivation are considered key determining factors related to the acquisition and maintenance of students' PA (Teixeira et al., 2012).

Based on the SDT and on the Theory of Planned Behavior (Ajzen, 1991), the trans-contextual model (TCM) was developed to conceptualize the transfer of self-determined motivation from educational contexts to out-of school contexts (Hagger and Chatzisarantis, 2016; Viciana et al., 2019). The premise behind this model is that motivation in these two contexts are likely to be highly salient in determining students' intentions and participation in PA. The TCM proposes three empirically testable propositions to explain the mechanisms by which teachers' support for motivation in school PE affects students' involvement in PA (Hagger et al., 2003). Firstly, students' perceptions of PE teachers' autonomy support are proposed to be related to their autonomous motivation toward activities performed in PE. Secondly, autonomous motivation in PE will predict autonomous motivation toward similar activities in leisure-time contexts. Thirdly, autonomous motivation in leisure-time contexts will predict students' future intentions to participate in similar activities, as well as actual behavioral engagement (Hagger and Chatzisarantis, 2016; Viciana et al., 2019). Specifically, the model suggests that attitude (i.e., students' perception of negative or positive evaluation of carrying out PA), subjective norm (i.e., students' perception of normative expectations to carry out or not to carry out PA), and perceived behavioral control (i.e., students' beliefs of ease or difficulty to perform PA) seem to be positively influenced by students' autonomous motivation for leisure-time PA (González-Cutre et al., 2014a,b). As a consequence, attitude, subjective norm, and perceived behavioral control will positively influence PA intention, which will ultimately manifest in behaviors that will encourage students to integrate PA as part of their lives (González-Cutre et al., 2014a,b; Hagger and Chatzisarantis, 2016). The systematic review conducted by Hagger and Chatzisarantis (2016) showed empirical support of the TCM across multiple studies conducted in the PE context, highlighting significant relationships between perceived autonomy support and self-determined motivation in PE (i.e., first proposition), between self-determined motivation in PE and in PA (i.e., second proposition), and between self-determined motivation and intention toward PA and actual PA engagement (i.e., third proposition).

In addition to the aforementioned individual theories related to students' PA promotion, a recent systematic review and meta-analysis found that the inclusion of behavior change techniques (Abraham and Michie, 2008) such as PA self-monitoring (e.g., activity wristbands) as part of the PA promotion programs has shown to be an effective strategy in increasing students' motivation toward PA practice, as well as the practice itself (Casado-Robles et al., 2022a,b). Furthermore, this systematic review and meta-analysis also found that incorporating a greater number of behavior modification strategies (e.g., educational counseling lessons or goal settings; Abraham and Michie, 2008) have also shown to be effective for promoting motivation toward PA among students from the PE setting (Casado-Robles et al., 2022a,b). In this sense, only four studies in the PE setting have examined the effects of intervention programs based on the use of activity wristbands, either alone or in combination with other behavior modification strategies, on high school students' PA practice promotion (Casado-Robles et al., 2022a,b). Unfortunately, to our knowledge, no previous studies have examined the effect of intermittent teaching units based on the use of activity wristbands and behavior modification strategies on students' PA practice mediators and PA practice itself. Additionally, although previous research has evidenced TCM to be a useful framework for understanding the role of self-determined motivation in PE in fostering PA (Hagger and Chatzisarantis, 2016), the current research evidence of PE-based intervention studies according to the postulates of the TCM is still scarce (Casado-Robles et al., 2022a). Especially incorporating innovative teaching unit structures together with activity wristbands and behavior modification strategies. The present study was designed to address these needs from a holistic perspective by investigating the effectiveness of an intermittent teaching unit based on the use of activity wristbands and behavior modification strategies and promoting an autonomy-supportive teaching style. Consequently, the main objective of the present study was to examine the effects of an intermittent teaching unit based on the use of activity wristbands and behavior modification strategies on high school students' perceptions of autonomy support, satisfaction of basic psychological needs, autonomous and controlled motivation toward PE and PA, intention to be physically active, and habitual PA levels. In line with the TCM tenets (Hagger and Chatzisarantis, 2016) and previous research that provide empirical support of the application of the TCM in the PE context (Sevil-Serrano et al., 2022), the main hypotheses were that students who perform the intermittent teaching unit based on the use of activity wristbands and behavior modification strategies will manifest: a) higher perceptions of autonomy support, satisfaction of basic psychological needs, and in consequence, higher autonomous and controlled motivation toward PE; b) higher motivation toward PA, intention to be physically active, and as a consequence, higher habitual PA levels compared with students in the control condition.

2. Materials and methods

2.1. Study design

The present study is reported according to the CONSORT for cluster-randomized trials guidelines (Campbell et al., 2012). The protocol conforms to the Declaration of Helsinki statements (64th WMA, Brazil, October 2013) and was approved by the

Ethical Committee for Human Studies at the University of Granada (code number: 1252/CEIH/2020). Recruitment of participants was carried out in December of 2021, and the intervention was done from January 2022 to May 2022. For practical reasons and due to the nature of the present study (i.e., pre-established classes in a school setting), a cluster randomized controlled trial design was used (Casado-Robles et al., 2022a). This study was non-blinded (treatments were not masked from the students or teacher), and parallel-grouped (study with two different treatments; Spieth et al., 2016), with three evaluation phases. The study has been registered as a clinical trial (ID: NCT05949463).

2.2. Participants

Firstly, the principal and the PE teachers of two state high-school centers of the province of Granada (Granada, Spain) chosen by convenience were contacted and informed about the study, requesting permission to conduct it. After obtaining the approval to carry out the present study, all 353 students (47.5% females) from the seventh to tenth grades of secondary education (i.e., 12–16 years old) were invited to participate in it. Students and their legal tutors were fully informed about the study features. Participants' signed written informed assent and their legal tutors' signed written informed consent were obtained before taking part in the study. According to the center's reports, all the students' families had a middle socioeconomic level.

The inclusion criteria were: a) being enrolled in the seventh to tenth grade at the secondary education level; b) participating in the normal PE lessons; c) being exempt of any health problem that would make them unable to engage in PA normally; d) presenting the corresponding signed written consent by their legal tutors, and e) presenting their own corresponding signed written assent. The exclusion criterion was defined as not having performed the evaluation of the dependent variables correctly at the pre-intervention, post-intervention and/or follow-up measures following the administration rules (being removed only for incomplete variables and not for the overall study).

2.3. Sample size

A priori sample size calculation was estimated with the Optimal Design Plus Empirical Evidence Software Version 3.01 for Windows. Parameters were set as follows: significance level $\alpha = 0.05$, number of participants per cluster $J = 16$, effect size $\delta = 0.60$ (Casado-Robles et al., 2022b), intra-class correlation coefficient $\rho = 0.01$, statistical power $(1 - \beta) = 0.80$, and dropout = 20% (Howie and Straker, 2016). A minimum final sample size of at least 112 participants (minimum initial sample size equal to 135) was estimated.

2.4. Randomization

To avoid contamination of treatments, randomization was conducted at the school-level, using a computerized random number generator. This was done before the pre-intervention evaluation was administered by an independent researcher blinded to the study aim and following a 1:1 ratio into the intermittent (IG) or control (CG) groups.

2.5. Measures

Data collection was carried out at the beginning and at the end of the teaching unit (pre-intervention and post-intervention, respectively), as well as at the end of the follow-up period. All evaluations were performed during two PE lessons' time by the same tester, instruments, and protocols. Prior to carrying out the intervention, students' sex and age information were obtained from school reports. Additionally, the students' anthropometric measures were taken following the International Standards for Anthropometric Assessment (Stewart et al., 2011). Moreover, students' previous experience with activity wristbands and current use of them were collected. Then, the first half of two PE lessons were used to evaluate students' psychological perceptions (i.e., autonomy support, basic psychological needs, motivation, and intention to be physically active) and self-reported habitual PA under silent conditions, leaving the second half for PA practice. At the beginning of the evaluation sessions, the researcher provided a complete explanation about how to correctly fill out the questionnaire. Students were asked for their maximum sincerity, and they were guaranteed the confidentiality of the obtained data. Although instructions on how to correctly respond to the questionnaire were printed at the top, the researcher was present during the whole evaluation session to clarify any question that might arise.

2.5.1. Anthropometric

Participants' body mass and height were measured in shorts, T-shirts, and barefoot. For the body mass measure, the student stood in the center of the scale (Seca, Ltd., Hamburg, Germany; accuracy = 0.1 kg) without support and with their weight distributed evenly on both feet. For the body height assessment, participants stood with their feet together with the heels, buttocks, and upper part of the back touching the stadiometer (Holtain Ltd., Crymmych, Pembs, United Kingdom; accuracy = 0.1 cm), and with the head placed in the Frankfort plane. Two measurements of both body mass and height were performed and the average of each was calculated (Stewart et al., 2011). Then, the body mass index was calculated as body mass divided by body height squared (kg/m^2). Finally, students' body weight status was categorized by the body mass index cut-points as overweight/obese (i.e., sex- and age-adjusted cut-point values equal to or higher than the equivalent value of 25 kg/m^2 at the age of 18 years) or non-overweight/obese (i.e., lower than the above-mentioned cut-point values) (Cole et al., 2000).

2.5.2. Perceived autonomy support

The PE teacher autonomy-support was assessed through the Spanish version of the Multi-Dimensional Perceived Autonomy Support Scale for PA (MD-PASS-PA; Trigueros et al., 2020). It consists of 15 items (five items per factor) that assessed organizational (e.g., "My PE teacher allows me to choose different exercise or sports options in my free time"), procedural (e.g., "My PE teacher gives me an overview of the different types of physical or sports exercise I can do in my free time"), and cognitive (e.g., "My PE teacher allows me to express my opinion about the physical exercise or sport I do in my free time") autonomy support. The Spanish version of MD-PASS-PA has shown adequate psychometric properties among adolescents (CFI = 0.98; IFI = 0.92; TLI = 0.98; SRMR = 0.04; RMSEA = 0.05; Cronbach's α = 0.82–0.86) (Trigueros et al., 2020).

2.5.3. Basic psychological needs

Students' perceptions of autonomy, competence, and relatedness satisfaction in PE and physical exercise were assessed using the Spanish version of the Basic Psychological Needs in Exercise Scale (BPNES; Sánchez and Núñez, 2007). It consists of 12 items (four items per factor) that assessed autonomy (e.g., "The physical exercise program that I follow is closely related to what I like and what interests me"), competence (e.g., "I think I have made tremendous progress with respect to the final goal that I pursue"), and relatedness (e.g., "I feel very comfortable with the other participants in the physical exercise program"). The items were preceded by the statement "When I do PA…." The Spanish version of BPNES has shown adequate psychometric properties among adolescents (CFI = 0.95; IFI = 0.95; SRMR = 0.05; RMSEA = 0.08; Cronbach's α = 0.74–0.87) (Sánchez and Núñez, 2007).

2.5.4. Motivation toward physical education

Participants' self-determined motivation toward PE was measured by the Spanish version of the Revised Perceived Locus of Causality Scale (PLOC-R; Trigueros et al., 2017). It consists of of 23 items spread over six dimensions (four items each except external regulation) that measure intrinsic motivation (e.g., "Because PE is nice"), amotivation (e.g., "But I do not really know why"), integrated (e.g., "Because it agrees with my way of life"), identified (e.g., "Because it is important for me to do PE"), introjected (e.g., "Because I would feel bad about myself if I did not"), and external regulation (e.g., "Because it is compulsory"). This questionnaire was preceded by the statement "I participate in PE lessons…." The autonomous (i.e., averaging intrinsic, integrated, and identified regulation) and controlled (i.e., averaging introjected and external) motivations were also calculated (Chemolli and Gagné, 2014). The Spanish version of the PLOC-R has shown adequate psychometric properties among adolescents (CFI = 0.95; TLI = 0.94; IFI = 0.95; SMR = 0.038 RMSEA = 0.067; Cronbach's alpha = 0.86–0.92) (Trigueros et al., 2017).

2.5.5. Self-determined motivation toward physical activity

Students' motivation toward PA was measured using the Spanish version of the Behavioral Regulation in Exercise Questionnaire (BREQ-3; González-Cutre et al., 2010). It consists of 23 items distributed into six dimensions (four items each except identified regulation) that measure intrinsic motivation (e.g., "Because I think exercise is fun"), amotivation (e.g., "I think exercising is a waste of time"), integrated (e.g., "Because it agrees with my way of life"), identified (e.g., "Because it is important to me to exercise regularly"), introjected (e.g., "Because I feel guilty when I do not practice it"), and external (e.g., "Because the others tell me that I should do it") regulation. This questionnaire was preceded by the statement: "I do PA…" The autonomous and controlled motivations were also calculated (Chemolli and Gagné, 2014). The Spanish version of the BREQ-3 has shown adequate psychometric properties among high-school students (CFI = 0.91; IFI = 0.91; RMSEA = 0.06; SRMR = 0.06; Cronbach's α = 0.66–0.87) (González-Cutre et al., 2010).

2.5.6. Intention to be physically active

Students' intention to be physically active in their free time was measured using the Spanish version of the Intention to partake in leisure-time PA questionnaire (Granero-Gallegos et al., 2014). It is composed of three items (e.g., "I intend to exercise at least three times a week for the next month"). The items were preceded by the sentence: "In my free time, after school…" The Spanish version of this questionnaire has shown adequate psychometric properties among adolescents (GFI = 1.00; RMR = 0.02; NFI = 1.00; NNFI = 0.99; CFI = 1.00; RMSEA = 0.03; Cronbach's α = 0.93) (Granero-Gallegos et al., 2014).

To adapt the scale of the five previous questionnaires to the Spanish students' school grades, a 10-point Likert-type was used according to previous studies (Casado-Robles et al., 2022a).

2.5.7. Habitual physical activity

Students' habitual PA was measured using the Physician-based Assessment and Counseling for Exercise questionnaire (PACE; Martínez-Gómez et al., 2009). It consists of two questions that measure how many days in the last week and in a habitual week at least 60 min of PA are performed. A 7-point Likert-type scale, ranging from 0 to 7 was used. The PACE questionnaire has shown adequate psychometric properties among high-school students (r = 0.43) (Martínez-Gómez et al., 2009).

2.6. Intervention

Both IG and CG students were required to participate in two mandatory PE lessons per week during the intervention period. Before the intervention, grounded in the SDT the PE teacher was trained to be autonomy and need-supportive during the intervention. The PE teacher autonomy and need-support training was focused on motivation and behavior change techniques provided by Teixeira et al. (2020). Furthermore, the guidelines for correctly delivering the lessons of the IG were designed by the researchers and given to the PE teacher. The main researcher supervised all the lessons and made sure all guidelines were taken into account during the program.

The IG students performed an intermittent teaching unit (Viciana and Mayorga-Vega, 2016) twice a week for eight weeks aimed at promoting healthy PA habits. Specifically, the last 15 min of each lesson were used. The rest of lessons' time other contents were worked on with no relation to any health PA habit (i.e., acrosport, badminton, basketball, volleyball, soccer and athletics). Based on recent literature (Casado-Robles et al., 2022b) as the main strategy of the teaching unit to promote regular PA practice, students wore an activity wristband the whole day (Xiaomi Mi Band 5) during the development of it. Reminders for an inactivity alert, achieved goal alert, and event alert for school recess and weekends were activated. In addition to the steps number, the activity wristband also measures heart rate, blood pressure, sleep time, distance, and calories. However, these options were hidden for participants in the activity wristband. At the beginning of the intervention, the main objective and activity wristband operation, including their specific mobile application (Mi Fit), were explained. Furthermore, with the aim of increasing participants interest, motivation, and commitment both teacher and IG participants signed a behavior change contract named "I improve my PA level" at the beginning of the intervention. Together with the contract, participants received a graph in which they had to reflect the average number of steps taken each week (data obtained from the Xiaomi Mi Fit). Next, participants of each class were organized in groups of four. Based on their preintervention PA levels, from the second to the last week of the intervention, a competition that consisted of achieving progressive step challenges, both individually and in teams, was established. During these last 15 min of the lessons, the information recorded by the activity wristband was analyzed in order to provide students with feedback of their daily PA habits. Additionally, together with the use of activity wristbands and PA goal challenges, educational counseling was applied (Casado-Robles et al., 2022b) in order to be need-supportive. Grounded in SDT motivation and behavior change techniques proposed by Teixeira et al. (2020), educational counseling included information about: (1) the benefits of regular PA practice; (2) PA recommendations, (3) types of PA that can be performed depending on the intensity and sedentary activities to avoid (PA pyramid), (4) healthy PA practice proposals for periods such as recess and leisure time, (5) barriers toward PA practice and their possible solutions, (6) sensitizing videos and news about PA practice, and (7) a list of 10 healthy behaviors. Also as part of the intervention, a personalized blog[1] with all the resources created for the intervention (e.g., tutorials of the activity wristband and mobile application operation, posters of the PA pyramid, PA recommendations, a list of 10 healthy behaviors, a list of PA practice proposals, barriers toward PA and solutions, as well as audiovisual material) was created. Moreover, a WhatsApp group was created for the IG in order to: a) promote students' satisfaction of basic psychological needs sending, every week from Monday to Saturday, six text messages (reviewed by a SDT specialist) (Ludwig et al., 2018), reminding students to synchronize the activity wristband with the mobile application (on Sunday), as well as to change the PA steps challenge. Finally, after the intervention, participants completed a six-week period in which they were encourage to autonomously maintain the PA challenge of 10,000 steps per day. They continued wearing the activity wristbands with the same reminders activated and were also encouraged to continue synchronizing the data of the activity wristband with the mobile application every week. However, no additional behavior modification strategies were applied.

Regarding the CG students, they also carried out two PE lessons a week during the intervention period. During these lessons, contents of handball, basketball, alternative sports and traditional games were developed. However, this group did not wear activity wristbands or receive any behavior modification specific strategy developed in the IG.

2.7. Statistical analysis

Descriptive statistics (mean ± standard deviation or percentage) for the general characteristics of the participants and dependent variables were calculated. Firstly, all the statistical tests assumptions were first checked for each dependent variable by common procedures (e.g., histograms and normal Q-Q plots for normality). Then, as exploratory analyses, the one-way analyses of variance (ANOVA) (continuous variables) and the chi-squared test (categorical variables) were conducted to examine potential differences in terms of general characteristics between the two groups. The internal consistency of the dependent variables measured by the questionnaires was examined with the Cronbach's alpha. Afterward, the effect of the activity wristband-based teaching unit on students' questionnaires scores was examined. All the participants were included in the statistical analyses regardless of adherence to the protocol (i.e., intention-to-treat approach). All the participants that did not follow protocol had failed to sustain a 100% attendance rate. Because the unit of intervention was the class, a Multilevel Linear Model with participants nested within classes and measures nested within participants as random effects, and with the between-group factor *group* (control, intermittent) and the within-group factor *time* (pre-intervention, post-intervention, follow-up) as fixed effects was selected (i.e., two-way mixed nested ANOVA/ANCOVA; Li et al., 2017). All the potential confounding variables (i.e., sex, grade, body mass, body height, body mass index, previous and current use of activity wristbands, and intervention attendance) were explored and used as covariables when necessary (see Table 1 footnotes). The maximum likelihood estimation method was used. Then, the *post-hoc* within-group pairwise comparisons with the Bonferroni adjustment for each group independently was carried out. Effect sizes were estimated using the Cohen's *d*. Finally, although an intention-to-treat approach was followed in the present study, as a sensitivity analyses, all the above-mentioned analyses were also carried out with a per-protocol approach (i.e., including the participants, taking into consideration their adherence to the protocol, that is, 100%). All statistical analyses were performed using the SPSS version 25.0 for Windows (IBM® SPSS® Statistics). The statistical significance level was set at $p \leq 0.05$.

3. Results

3.1. Final sample and general characteristics

Figure 1 shows the flow chart of the participants included in the present study. From the 353 students that were invited to participate in the present study, 175 students (45.1% females) agreed and met the inclusion criteria. However, 173 students (45.7% females) passed the exclusion criterion. A total of 70–75 and 88–98 participants from CG and IG, respectively, had dependent variables with completed data in the three measures. Table 2 shows the general characteristics of the included participants. The results of the one-way ANOVA and the chi-square test did not show statistically significant differences in terms of general characteristics between the two groups ($p > 0.05$), except for the body height and weight status ($p < 0.05$). Regarding the attendance rate, the IG participants obtained an average of 92.6% (number of participants with an attendance rate 50–59% = 3; 60–69% = 3; 70–79% = 4; 80–89% = 22; 90–99% = 8; 100% = 58). In the sample of the present study, the internal consistency of all the dependent variables measured by dimensional questionnaires was above 0.70 (from 0.76 to 0.92).

3.2. Effect of the activity wristband-based teaching unit on students' questionnaires scores

Table 1 shows the effect of the intermittent teaching unit on students' questionnaires scores. The Multilevel Linear Model results,

1 https://pulserasef.blogspot.com/

TABLE 1 Effect of the intermittent teaching unit on students' questionnaires scores.

	Pre-intervention (1)	Post-intervencion (2)	Follow-up (3)	Multilevel linear model[a]			Effect sizes (*d*)[b]		
	Mean (SE)	Mean (SE)	Mean (SE)	*- 2LL*	*F*	*p*	1–2	2–3	1–3
Cognitive autonomy									
Control ($n = 75$)	7.3 (0.2)	7.1 (0.2)	7.1 (0.2)	1863.012	3.182	0.044	0.34	−0.05	0.28
Intermittent ($n = 97$)	8.7 (0.2)	9.1 (0.1)*	9.0 (0.2)						
Procedural autonomy									
Control ($n = 75$)	6.4 (0.2)	6.3 (0.2)	6.4 (0.2)	2005.722	8.956	< 0.001	0.61	−0.06	0.55
Intermittent ($n = 97$)	7.7 (0.2)	8.8 (0.2)***	8.8 (0.2)‡‡‡						
Organizational autonomy									
Control ($n = 75$)	6.9 (0.2)	7.1 (0.2)	7.0 (0.2)	1885.318	1.379	0.254	0.20	0.04	0.24
Intermittent ($n = 97$)	8.4 (0.2)	9.0 (0.2)**	8.9 (0.2)‡‡						
BPN autonomy									
Control ($n = 75$)	7.8 (0.2)	7.6 (0.2)	7.7 (0.2)	1944.602	5.082	0.007	0.10	0.35	0.45
Intermittent ($n = 97$)	7.9 (0.2)	8.0 (0.2)	8.7 (0.2)†††/‡‡‡						
BPN competence									
Control ($n = 75$)	7.8 (0.2)	7.7 (0.2)	7.9 (0.2)	2016.680	0.343	0.710	0.02	0.10	0.12
Intermittent ($n = 97$)	8.5 (0.2)	8.5 (0.2)	8.8 (0.2)						
BPN relatedness[c]									
Control ($n = 75$)	7.7 (0.2)	7.7 (0.2)	7.8 (0.2)	1875.821	5.943	0.003	0.09	0.34	0.43
Intermittent ($n = 97$)	7.9 (0.2)	8.0 (0.2)	8.7 (0.2)†††/‡‡‡						
Autonomous motivation toward PE[d]									
Control ($n = 75$)	6.8 (0.2)	6.9 (0.2)	7.2 (0.2)	2038.821	0.108	0.898	0.05	0.01	0.07
Intermittent ($n = 98$)	7.8 (0.2)	8.0 (0.2)	8.3 (0.2)						
Controlled motivation toward PE									
Control ($n = 75$)	4.7 (0.3)	5.0 (0.2)	4.9 (0.3)	2254.403	2.155	0.118	−0.02	0.35	0.33
Intermittent ($n = 98$)	4.7 (0.2)	5.0 (0.2)	5.6 (0.2)†/‡‡						
Autonomous motivation toward PA[d]									
Control ($n = 75$)	7.4 (0.2)	7.6 (0.2)	7.4 (0.2)	1954.631	4.402	0.013	−0.12	0.39	0.27
Intermittent ($n = 95$)	7.7 (0.2)	7.7 (0.2)	8.2 (0.2)††/‡						
Controlled motivation toward PA									
Control ($n = 75$)	3.2 (0.2)	4.2 (0.2)***	4.2 (0.2)‡‡‡	2061.107	10.682	< 0.001	−0.51	−0.26	−0.77
Intermittent ($n = 96$)	3.8 (0.2)	3.8 (0.2)	3.4 (0.2)						
Intention to be physically active									
Control ($n = 75$)	8.4 (0.3)	8.1 (0.3)	8.5 (0.2)	2152.298	0.651	0.522	0.15	−0.16	−0.01
Intermittent ($n = 97$)	8.7 (0.2)	8.8 (0.2)	8.8 (0.2)						
Habitual PA[c]									
Control ($n = 75$)	3.5 (0.2)	3.8 (0.2)	3.7 (0.2)	1781.809	5.308	0.006	0.10	0.33	0.43
Intermittent ($n = 98$)	3.7 (0.2)	4.2 (0.2)**	4.6 (0.2)†/‡‡‡						

SE, Standard error; - 2LL = -2 log-likelihood; BPN, Basic psychological needs; PE, Physical Education; PA, Physical activity; [a]Multilevel Linear Model with participants nested within classes and measures nested within participants as random effects, and with the between-subjects factor group (control, intermittent) and the within-subject factor time (pre-intervention, post-intervention, follow-up) as fixed effects was selected (i.e., two-way mixed nested ANOVA/ANCOVA); *Post-hoc* within-subject pairwise comparisons with Bonferroni adjustment for each group independently: Pre-post-intervention change (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); Post-intervention-post-maintenance change († $p < 0.05$, †† $p < 0.01$, ††† $p < 0.001$), and pre-intervention-post-maintenance change (‡ $p < 0.05$, ‡‡ $p < 0.01$, ‡‡‡ $p < 0.001$); The covariables used for each analysis were as follows: [c]Sex and [d]Body height; [b]Cohen's d effect size.

followed by the within-group pairwise comparisons, showed that the IG students statistically significantly improved cognitive and procedural autonomy scores from pre- to post-intervention ($p < 0.05$), as well as procedural autonomy scores from pre-intervention to follow-up ($p < 0.01$); and they also statistically significantly improved autonomy and relatedness basic psychological needs, and autonomous motivation toward PA scores from post-intervention to follow-up, and from pre-intervention to follow-up ($p < 0.05$).

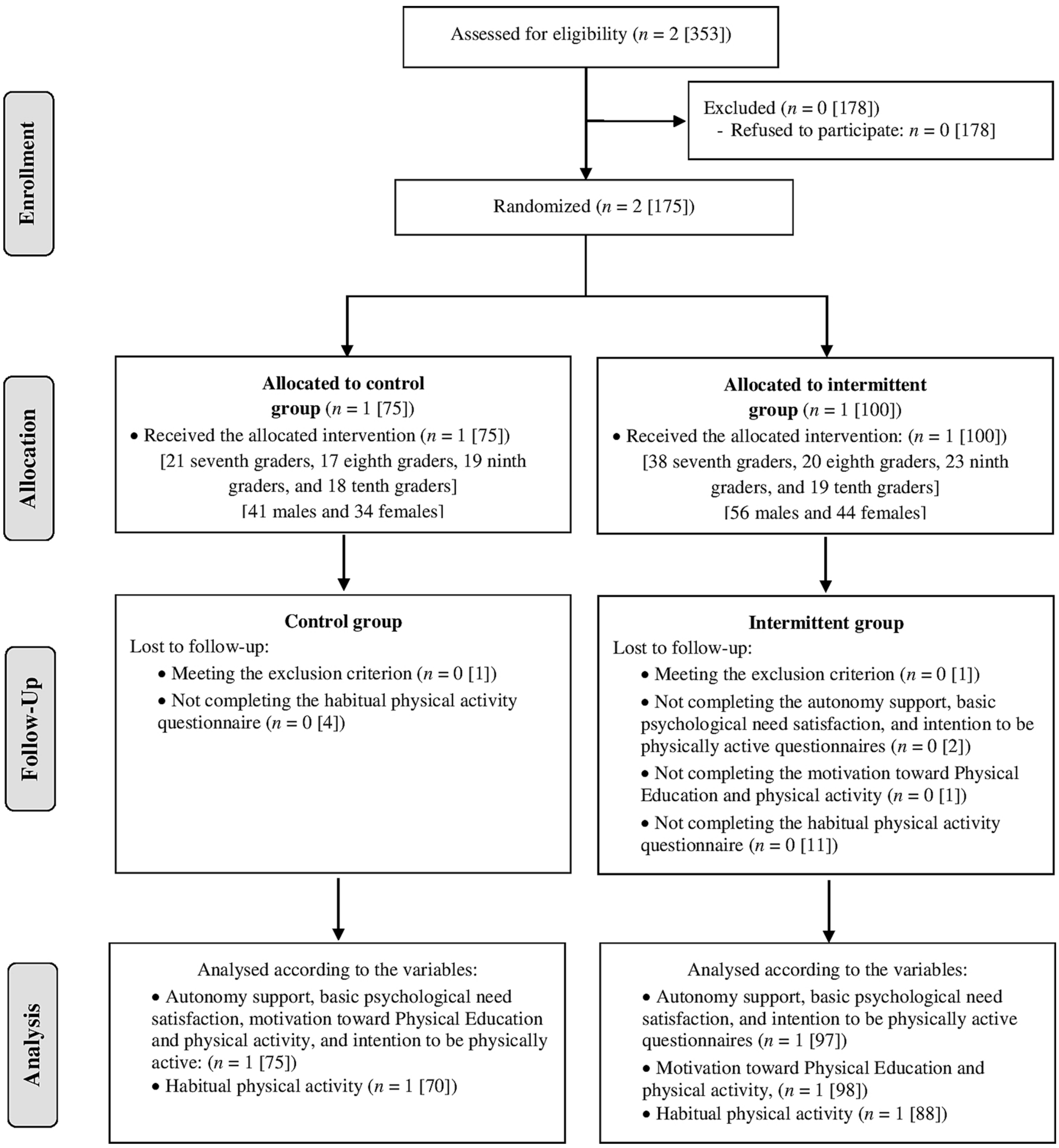

FIGURE 1
Flow chart of participants included in the present study. All numbers are school centers [students].

Moreover, the results showed that IG students statistically improved the habitual PA scores from pre- to post-intervention, from post-intervention to follow-up, and from pre-intervention to follow-up ($p < 0.05$). However, the Multilevel Linear Model results, followed by the within-group pairwise comparisons, showed that the CG students statistically significantly improved controlled motivation toward PA scores from pre- to post-intervention and from pre-intervention to follow-up ($p < 0.001$). On the other hand, for the rest of variables statistically significant differences were not found ($p > 0.05$).

3.3. Sensitivity analysis

Supplementary Table S1 shows the sensitivity analysis (i.e., per-protocol approach) of the effect of the intermittent teaching unit on students' questionnaires scores. The results with the per-protocol approach found similar outcomes as with the main analysis (i.e., intention-to-treat approach). Exceptionally, the Multilevel Linear Model results, followed by the within-group pairwise comparisons, showed that with the per-protocol approach the IG students statistically significantly improved controlled motivation toward PE

TABLE 2 General characteristics of the included participants.

	Total (n = 173)	Control (n = 75)	Intermittent (n = 98)	F/χ^2	p^a
Age (years)[b]	13.3 (1.2)	13.4 (1.2)	13.2 (1.3)	1.045	0.308
Sex (females/males)[c]	45.7/54.3	44.0/56.0	46.9/53.1	0.148	0.701
Grade (7th/8th/9th/10th)[c]	34.1/21.4/24.3/20.2	28.0/22.7/25.3/24.0	38.8/20.4/23.5/17.3	2.538	0.468
Body mass (kg)[b]	55.2 (12.3)	56.1 (10.3)	54.5 (13.7)	0.721	0.397
Body height (cm)[b]	161.6 (9.5)	164.0 (9.6)	159.8 (9.1)	8.759	0.004
Body mass index (kg/m^2)[b]	21.0 (3.8)	20.8 (2.9)	21.2 (4.3)	0.553	0.458
Overweight-obese (no/yes)[c]	74.4/25.6	82.7/17.3	68.0/32.0	4.752	0.029
Previous experience with activity wristbands (no/yes)[c]	29.7/70.3	31.1/68.9	28.6/71.4	0.127	0.721
Current use of activity wristbands (no/yes)[c]	69.8/30.2	63.5/36.5	74.5/25.5	2.408	0.121
Habitual PA (days/week)[b,d]	3.6 (1.6)	3.5 (1.7)	3.7 (1.6)	0.355	0.552

[a]Significance level from the one-way analysis of variance for continous variables and the chi squared test for categorical variables; Data are reported as mean (standard deviation) for continous variables[b] and as percentage for categorical variables[c]; [d]Baseline (pre-intervention) PACE scores.

scores from pre-intervention to follow-up ($p < 0.001$; for the main analyses the interaction effect p value was >0.05). Moreover, while with both approaches IG students statistically significantly improved autonomous motivation toward PA scores from post-intervention to follow-up ($p < 0.01$), with the per-protocol approach was not statistically significant from pre-intervention to follow-up ($p > 0.05$) as it was for the intention-to-treat approach ($p < 0.05$).

4. Discussion

The main objective of the present study was to examine the effects of an intermittent teaching unit based on the use of activity wristbands and behavior modification strategies on high school students' perceptions of autonomy support, satisfaction of basic psychological needs, autonomous and controlled motivation toward PE and PA, intention to be physically active, and habitual PA levels. Little research has examined the effects of intervention programs based on the use of activity wristbands on adolescents PA practice mediators, either alone or in combination with other strategies following the tenets of TCM. Results of this study have shown that the intermittent teaching unit improved students' cognitive and procedural autonomy support, as well as habitual PA levels from pre- to post-intervention. Interpreting the results under the tenets of the TCM, it seems that the PE intervention, centered on the promotion of students' autonomy for the participation in PA could increase their perception of autonomy support. This could be due to that: 1) the intervention was based on a continuous analysis of the information recorded by the activity wristband which provided students with feedback of their daily PA habits (Casado-Robles et al., 2022b), and 2) the educational PA counseling that included a wide variety of information about PA practice (Neil-Sztramko et al., 2021; Casado-Robles et al., 2022b). These findings are in line with previous school-based PA interventions where PE teachers support students' leisure-time PA (González-Cutre et al., 2014a; Casado-Robles et al., 2022a; Sevil-Serrano et al., 2022). Regarding the absence of differences on the organizational autonomy factor, it could be because, although the PE teacher suggested a variety of activities that students could perform in different contexts (i.e., school recess and leisure time), most of them were based on achieving steps. Therefore, other activities like swimming, riding a bike or skipping rope, among others, were not suggested. This could lead students to perceived that these activities are the only ones that could be performed in the aforementioned contexts. However, it is important to highlight that they were suggestions, but students had the opportunity to choose what they considered more suitable to achieve the step goals proposed.

According to the TCM, autonomy support in PE will predict autonomous motivation in PE, which in turn influences his/her autonomous motivation toward similar activities in leisure-time contexts (Hagger and Chatzisarantis, 2016). Contrary to the TCM proposition (Hagger and Chatzisarantis, 2016) and past evidence (Cheon and Reeve, 2013; Sevil-Serrano et al., 2022), in the present study the increase showed in autonomy support was not translated into a positive effect in students' motivational outcomes to leisure-time PA (i.e., basic psychological needs satisfaction and motivation toward PE and PA) from pre- to post-intervention. However, none of these studies used activity wristbands for promoting PA practice. Similar to the present study, Kerner and Goodyear (2017) examined the effect of wearing an activity wristband during eight weeks on students' motivation toward PA. These authors found that activity wristbands negatively impacted students' motivation toward PA. Nevertheless, this study did not apply any specific strategy during the intervention period. On the contrary, a recent systematic review and meta-analysis found that the inclusion of activity wristbands together with other behavior modification strategies as part of the PA promotion programs is an effective strategy to increase students' motivation toward PA practice (Casado-Robles et al., 2022b). In this sense, although the teaching unit applied in this study was centered on teaching the students about the importance of practicing regular PA and included strategies that have shown to be effective for promoting students' PA practice mediators (e.g., motivation; Casado-Robles et al., 2022b), maybe the time used of each teaching unit lesson (i.e., 15 min), as well as the total length of the intervention (Neil-Sztramko et al., 2021), were not enough to produce an improvement in these variables. González-Cutre et al. (2016) pointed out that strategies of PA promotion require time to become operational and modify students' behavior. Moreover, group competition established during the intervention could also affect the improvement of students' autonomy, competence and relatedness needs, since when students lose in competitions or do not achieve the objective (i.e., progressive steps challenges), perceptions of competence and intrinsic motivation decrease (Kerner and Goodyear, 2017). Additionally, another possible explanation of the lack of change in these variables in the IG could be the high starting values of IG studens for these variables which would be difficult to increase (González-Cutre et al., 2014b). Perhaps, if the intervention included other support agents like parents or tutors (Sevil-Serrano et al., 2022), as well as an innovative methodology like gamification, which have been shown to be effective strategies for improving students' motivation (Arufe-Giráldez et al., 2022), an increase in this variable could be achieved.

Regarding students' intention to be physically active, results of this study showed that the intermittent teaching unit did not influence this PA mediator. These results are opposite to previous studies carried out in the PE setting that have also applied autonomy-supportive teaching styles and have found that student's intention to be physically active increased (Cheon and Reeve, 2013; Casado-Robles et al., 2022a). Nevertheless, results obtained in the present study with this variable seem logical considering that previous PA practice mediators according to the TCM (i.e., basic psychological needs and motivation) did not change either. Furthermore, another factor that could explain this result is the high values of intention to be physically active (8.7 out of 10 points) reported by IG students before the intervention. That is, it could be possible that students perceived that they already were motivated enough for PA practice without the need for extra motivation with the proposed intervention (Owen et al., 2014). Therefore, it is important to highlight that the maintenance of a high baseline motivation is an important achievement of the present study. In this sense, it seems necessary to study which specific strategies should be implemented in the interventions with these types of students to help them maintain their intention toward PA practice, or even to continue increasing it, therefore obtaining greater health-related benefits (World Health Organization, 2020). Surprisingly, after the intervention statistically significant differences were found in habitual PA levels of the IG students. These findings are very valuable, since although previous PA practice mediators did not increase, IG students reported that they performed PA with a higher frequency after the intervention. These results may be attributable to the higher perception in autonomy support from the PE teacher (González-Cutre et al., 2016), as well as by the use of PA wristbands and educational counseling provided during the intervention regarding the importance of practicing regular PA (Casado-Robles et al., 2022b). Additionally, although students' motivational outcomes to leisure-time PA (i.e., basic psychological needs satisfaction, motivation toward PE and PA, and intention to practice) did not improve after the intervention, the high values maintained in all of them suggest that the third preposition of TCM could be confirmed (Hagger and Chatzisarantis, 2016), and are consistent with previous studies (González-Cutre et al., 2016; Casado-Robles et al., 2022a; Sevil-Serrano et al., 2022). Contrary to these results, Bronikowski et al. (2016) found that after an eight-week intervention using activity wristbands, self-reported PA assessed using the same self-report measure (Martínez-Gómez et al., 2009) did not change. A possible explanation could be that these authors only applied one strategy to modify students' PA behavior (i.e., use of activity wristband), which it has been suggested to be less effective in comparison with multi-dimensional interventions that combine several strategies to influence PA practice mediators (Casado-Robles et al., 2022a,b).

To verify whether the effects are maintained over time, a follow-up measurement 6 weeks after the end of the intervention was performed. The results revealed that habitual PA level changes were maintained and even improved, meanwhile differences in perceived autonomy support and intention to be physically active were not found. These results seem logical for the following reasons. Firstly, no autonomy support from PE was applied during this period of the study. Secondly, as it has been mentioned previously, strategies of PA promotion require time to become operational and modify students' behavior (González-Cutre et al., 2016). Consequently, these results suggest that it would be necessary to increase the length of interventions to achieve greater effectiveness in PA practice mediators. In this sense, although no behavior modification strategies were applied (except the use of an activity wristband), students had the objective of autonomously maintaining at least 10,000 steps per day. However, the main difference was that there was no competition between students for achieving more steps. This fact could lead students to feel more comfortable with this part of the intervention program, therefore contributing to experiencing higher perceptions of autonomy need, as well as better integration (i.e., relatedness need) with their peers. Regarding competence need, the establishment of a specific step target (i.e., 10,000 steps/day) to be autonomously maintained might be the cause of the absence of differences in this variable. According to previous literature (Kerner and Goodyear, 2017) when students are only focused on the PA outcome (step target) rather than the process, it could lead to feeling that they are unable to complete the step target set in the activity wristband, making them think they are failing, which could negatively impact their sense of competence.

Additionally, new positive differences were observed in autonomy and relatedness needs and autonomous motivation toward PA. On the basis of the theorical tenets of TCM (Hagger and Chatzisarantis, 2016), students' satisfaction of basic psychological needs in leisure-time PA could significantly contribute to autonomous motivation toward PE and this to autonomous motivation toward PA. Although motivation toward PE did not increase in a statistically significant manner from the post-intervention to the end of the follow-up period, it is important to highlight that the average punctuation in this variable was maintained and slightly increased, with already high values at the follow-up measurement. Finally, although no differences were found on students' intention to be physical, habitual PA levels increased again. In this sense, in addition to the responsibility of autonomously maintaining the PA practice with the help of activity wristbands that students had, the greater values in autonomous motivation toward PA obtained could help to increase their habitual PA levels (Hagger and Chatzisarantis, 2016). Previous similar studies carried out in the PE setting observed that the habitual PA levels decrease after the follow-up period (e.g., Ridgers et al., 2021). However, it is important to point out that (Ridgers et al., 2021) follow-up was six months after the end of the intervention. The later follow-up together with the fact that no additional objectives were proposed to students during this period of time (i.e., do your best steps per day) could be the reasons for the lack of differences in habitual PA levels.

The main strength of the present study was that, this is the first study that examines the effects of an intermittent teaching unit based on the use of activity wristbands and behavior modification strategies on students' perceptions of autonomy support, the satisfaction of basic psychological needs, autonomous and controlled motivation toward PE and PA, intention to be physically active, and habitual PA levels. Another strength is the inclusion of a follow-up measure to examine the long-term effectiveness of the program as suggested by previous literature (Nguyen et al., 2016). Moreover, because of the nature of the context (i.e., school) and with the objective of keeping the ecological validity, the use of a cluster-randomized controlled trial design (balanced by grade) was more appropriate for the present research objective (Campbell et al., 2012). Furthermore, the comparison with a CG that did not wear PA activity wristbands or receive any behavior modification strategy, allows us to check that the effects obtained are due to the intervention. Finally, the evaluation of the effect of the teaching unit with a Multilevel Linear Model with participants nested within classes and measures nested within participants as random effects, represents an advancement with respect to the commonly applied analyses (Li et al., 2017).

This study also has some limitations that should be acknowledged. Firstly, the non-probabilistic and relatively small sample size provides a lower generalization power. This limits the generalizability of the obtained outcomes to the particular studied population and context. However, due to human, time, and material resource restrictions, a probabilistic and larger sample could not be examined. Moreover, the teaching unit length could have been a limitation to achieving greater effects on the PA mediator variables. However, considering the large volume of objectives that have to be developed throughout the academic year with a very limited time for the PE subject (Casado-Robles et al., 2019), the purpose was to perform a real study that would be feasible to perform in the context of PE. Additionally, and according to the SDT framework which distinguishes six specific types of PE teacher interpersonal behaviors, only one of them was studied (i.e., autonomy support). Finally, SDT framework studied was only focused on the bright motivation path (i.e., need-supportive environment-need satisfaction-autonomous motivation-adaptive outcomes). That is, the need frustration and need-thwarting behaviors which are part of the dark motivational path were not studied. Future studies should include a probabilistic and larger sample, which provide a higher generalization of the obtained outcomes. Additionally, it would be interesting to reproduce the present study including additional social agents like parents or school teachers with the aim of checking if better results on students' PA practice mediators are obtained. Moreover, it would also be interesting reproducing this study and measuring PA objectively to check if the strategies applied really influence students' PA levels. Even, it would be interesting including a qualitative evaluation (i.e., interviews or focus groups) of the intervention program. This, would help us to deeply understand the specific perceptions and/or situations that students experience during the intervention. That is, the reasons why some motivational effects appear or not after the intervention, or why they are maintained or not over time.

4.1. Practical implications

Promoting PA practice from the PE setting it is not an easy task considering PE planning limitations (Casado-Robles et al., 2019). Moreover, influencing PA practice psychological mediators represents a behavior change that requires time (Neil-Sztramko et al., 2021). Results of this study suggest that planning intermittent teaching units based on activity wristbands and behavior modification strategies seems to be a more efficient distribution of the learning time than using the entire lesson for an intensive period. In this sense, achieving the PA psychological mediators change progressively during more time through intermittent teaching units, instead of concentrating all the designated time to get this target in a few weeks, could guarantee its maintenance over time. Moreover, the results obtained in the present study may guide PE teachers to design effective interventions with a different distribution of the learning time that in addition to modifying student's PA mediators, can affect their real PA engagement, therefore reducing their high levels of physical inactivity. Additionally, the results of this research also showed that apart from influencing PA psychological mediators, other PE curricular objectives can be developed during the same lessons' time, solving several PE planning difficulties such as the reduced time allocation to PE or the high volume of curricular contents and objectives that have to be developed during the academic course. Finally, the present study opens the way for developing potentially effective interventions applying this innovative teaching unit structure incorporating other strategies that have shown being effective for modifying PA psychological mediators in order to potentiate the outcomes obtained after the intervention. To illustrate this, as part of the intervention of other support agents like parents or tutors (Sevil-Serrano et al., 2022), and even, innovative active learning methodologies such as gamification (Arufe-Giráldez et al., 2022), which have shown being effective for improving student's autonomous motivation, should be included.

5. Conclusion

An intermittent teaching unit based on the use of activity wristbands and behavior modification strategies was effective for improving students' perceptions of autonomy support and habitual PA levels. However, after six weeks of autonomous PA practice with the activity wristbands, new effects were observed in students' autonomy and relatedness needs, as well as in autonomous motivation toward PA. What is more, habitual PA levels also increase after the follow-up period. These results suggest that increasing the length of the intervention would allow to increase all psychological PA practice mediators, therefore, leading to actual PA engagement. Additionally, findings obtained in the present study and future similar studies, may help PE teachers and the scientific community to understand and design effective PA promotion programs based on behavior change theories that combine key aspects such as innovative teaching unit structures, PA self-monitoring, and behavior modification strategies that can affect student's PA practice mediators and therefore their PA engagement.

Data availability statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics statement

The studies involving humans were approved by Ethical Committee for Human Studies at the University of Granada (code number: 1252/CEIH/2020). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians.

Author contributions

SG-R, DM-V, CC-R, and JV contributed to the conception and design of the study. SG-R and CC-R were responsible for collecting the data. DM-V carried out the analysis and interpretation of the data. SG-R and JV drafted the manuscript. All authors contributed to the article and approved the final version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1228925/full#supplementary-material

References

Abraham, C., and Michie, S. (2008). A taxonomy of behavior change techniques used in interventions. *Health Psychol.* 27, 379–387. doi: 10.1037/0278-6133.27.3.379

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi: 10.1016/0749-5978(91)90020-T

Arufe-Giráldez, V., Sanmiguel-Rodríguez, A., Ramos-Álvarez, O., and Navarro-Patón, R. (2022). Gamification in physical education: a systematic review. *Educ. Sci.* 12:540. doi: 10.3390/educsci12080540

Association for Physical Education. (2020). *Health position paper*. Worcester: Association for Physical Education.

Borde, R., Smith, J. J., Sutherland, R., Nathan, N., and Lubans, D. R. (2017). Methodological considerations and impact of school-based interventions on objectively measured physical activity in adolescents: a systematic review and meta-analysis. *Obes. Rev.* 18, 476–490. doi: 10.1111/obr.12517

Bronikowski, M., Bronikowska, M., and Glapa, A. (2016). Do they need goals or support? A report from a goal-setting intervention using physical activity monitors in youth. *Int. J. Environ. Res. Public Health* 13:914. doi: 10.3390/ijerph13090914

Campbell, M. K., Piaggio, G., Elbourne, D. R., and Altman, D. G. (2012). Consort 2010 statement: extension to cluster randomised trials. *BMJ* 345, 1–21. doi: 10.1136/bmj.e5661

Casado-Robles, C., Guijarro-Romero, S., and Mayorga-Vega, D. (2019). "Planificación en Educación Física mediante unidades didácticas innovadoras para incrementar los niveles de actividad física habitual de los escolares" in *Investigación, Innovación docente y TIC. Nuevos Horizontes Educativos*. eds. S. Alonso García, J. Romero Rodríguez, C. Rodríguez-Jiménez and J. Sola Reche (Madrid: Dykinson S.L.), 283–296.

Casado-Robles, C., Viciana, J., Guijarro-Romero, S., and Mayorga-Vega, D. (2022a). Effect of an inside–outside school alternated teaching unit of knowledge of the environment for practicing physical activity: a cluster randomized control trial. *J. Teach. Phys. Educ.* 41, 149–158. doi: 10.1123/jtpe.2020-0132

Casado-Robles, C., Viciana, J., Guijarro-Romero, S., and Mayorga-Vega, D. (2022b). Effects of consumer-wearable activity tracker-based programs on objectively measured daily physical activity and sedentary behavior among school-aged children: a systematic review and meta-analysis. *Sports Med.-Open* 8:18. doi: 10.1186/s40798-021-00407-6

Chemolli, E., and Gagné, M. (2014). Evidence against the continuum structure underlying motivation measures derived from self-determination theory. *Psychol. Assess.* 26, 575–585. doi: 10.1037/a0036212

Cheon, S., and Reeve, J. (2013). Do the benefits from autonomy-supportive PE teacher training programs endure? A one-year follow-up investigation. *Psychol. Sport Exerc.* 14, 508–518. doi: 10.1016/j.psychsport.2013.02.002

Cole, T. J., Bellizzi, M. C., Flegal, K. M., and Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 320, 1240–1243. doi: 10.1136/bmj.320.7244.1240

Deci, E., and Ryan, R. (1985). *Intrinsic motivation and self-determination in human behavior*. New York, NY: Plenum.

European Commission/EACEA/Eurydice. (2013). *Physical education and sport at school in Europe Eurydice report*. Luxembourg: Publications Office of the European Union.

González-Cutre, D., Ferriz, R., Beltrán-Carrillo, V. J., Andrés-Fabra, J. A., Montero-Carretero, C., Cervelló, E., et al. (2014a). Promotion of autonomy for participation in physical activity: a study based on the trans-contextual model of motivation. *Educ. Psychol.* 34, 367–384. doi: 10.1080/01443410.2013.817325

González-Cutre, D., Sicilia, Á., Beas-Jiménez, M., and Hagger, M. S. (2014b). Broadening the trans-contextual model of motivation: a study with Spanish adolescents. *Scand. J. Med. Sci. Sports* 24, e306–e319. doi: 10.1111/sms.12142

González-Cutre, D., Sicilia, A., and Fernández, A. (2010). Hacia una mayor comprensión de la motivación en el ejercicio físico: Medición de la regulación integrada en el contexto español. *Psicothema* 22, 841–847.

González-Cutre, D., Sierra, A. C., Beltrán-Carrillo, V. J., Peláez-Pérez, M., and Cervelló, E. (2016). A school-based motivational intervention to promote physical activity from a self-determination theory perspective. *J. Educ. Res.* 111, 320–330. doi: 10.1080/00220671.2016.1255871

Granero-Gallegos, A., Baena-Extremera, A., Pérez-Quero, F. J., Ortiz-Camacho, M. M., and Bracho-Amador, C. (2014). Validación española del 'intention to partake in leisure-time physical activity'. *Retos* 26, 40–45. doi: 10.47197/retos.v0i26.34392

Guijarro-Romero, S., Mayorga-Vega, D., Casado-Robles, C., and Viciana, J. (2020). Effect of a physical education-based fitness intermittent teaching unit on high school students' cardiorespiratory fitness: a cluster-randomized controlled trial. *J. Sports Med. Phys. Fit.* 60, 700–708. doi: 10.23736/S0022-4707.20.10328-1

Guthold, R., Stevens, G. A., Riley, L. M., and Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child. Adolesc. Health* 4, 23–35. doi: 10.1016/S2352-4642(19)30323-2

Hagger, M. S., and Chatzisarantis, N. L. D. (2016). The trans-contextual model of autonomous motivation in education: conceptual and empirical issues and meta-analysis. *Rev. Educ. Res.* 86, 360–407. doi: 10.3102/0034654315585005

Hagger, M. S., Culverhouse, T., Chatzisarantis, N. L. D., and Biddle, S. J. H. (2003). The processes by which perceived autonomy support in physical education promotes leisure-time physical activity intentions and behavior: a trans-contextual model. *J. Educ. Psychol.* 95, 784–795. doi: 10.1037/0022-0663.95.4.784

Howie, E. K., and Straker, L. M. (2016). Rates of attrition, non-compliance and missingness in randomized controlled trials of child physical activity interventions using accelerometers: a brief methodological review. *J. Sci. Med. Sport* 19, 830–836. doi: 10.1016/j.jsams.2015.12.520

Kerner, C., and Goodyear, V. A. (2017). The motivational impact of wearable healthy lifestyle technologies: a self-determination perspective on Fitbits with adolescents. *Am. J. Health Educ.* 48, 287–297. doi: 10.1080/19325037.2017.1343161

Kwasnicka, D., Dombrowski, S. U., White, M., and Sniehotta, F. (2016). Theoretical explanations for maintenance of behaviour change: a systematic review of behaviour theories. *Health Psychol. Rev.* 10, 277–296. doi: 10.1080/17437199.2016.1151372

Li, W., Xiang, P., Chen, Y., Xie, X., and Li, Y. (2017). Unit of analysis: impact of Silverman and Solmon's article on field-based intervention research in physical education in the U.S.a. *J. Teach. Phys. Educ.* 36, 131–141. doi: 10.1123/jtpe.2016-0169

Love, R., Adams, J., and van Sluijs, E. M. F. (2019). Are school-based physical activity interventions effective and equitable? A meta-analysis of cluster randomized controlled trials with accelerometer-assessed activity. *Obes. Rev.* 20, 859–870. doi: 10.1111/obr.12823

Ludwig, K., Arthur, R., Sculthorpe, N., Fountain, H., and Buchan, D. S. (2018). Text messaging interventions for improvement in physical activity and sedentary behavior in youth: systematic review. *JMIR Mhealth Uhealth* 6:e10799. doi: 10.2196/10799

Martínez-Gómez, D., Martínez-De-Haro, V., Del-Campo, J., Zapatera, B., Welk, G. J., Villagra, A., et al. (2009). Validez de cuatro cuestionarios para valorar la actividad física en adolescentes españoles. *Gac. Sanit.* 23, 512–517. doi: 10.1016/j.gaceta.2009.02.013

Mayorga-Vega, D., Martínez-Baena, A., and Viciana, J. (2018). Does school physical education really contribute to accelerometer-measured daily physical activity and non sedentary behaviour in high school students? *J. Sports Sci.* 36, 1913–1922. doi: 10.1080/02640414.2018.1425967

Mayorga-Vega, D., Montoro-Escaño, J., Merino-Marban, R., and Viciana, J. (2016). Effects of a physical education-based programme on health-related physical fitness and its maintenance in high school students: a cluster-randomized controlled trial. *Eur. Phys. Educ. Rev.* 22, 243–259. doi: 10.1177/1356336X15599010

Neil-Sztramko, S. E., Caldwell, H., and Dobbins, M. (2021). School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst. Rev.* 2021:CD007651. doi: 10.1002/14651858.CD007651.pub3

Nguyen, S., Häcker, A. L., Henderson, M., Barnett, T., Mathieu, M. E., Pagani, L., et al. (2016). Physical activity programs with post-intervention follow-up in children: a comprehensive review according to categories of intervention. *Int. J. Environ. Res. Public Health* 13:664. doi: 10.3390/ijerph13070664

Owen, K., Smith, J., Lubans, D., Ng, J., and Lonsdale, C. (2014). Self-determined motivation and physical activity in children and adolescents: a systematic review and meta-analysis. *Prev. Med.* 67, 270–279. doi: 10.1016/j.ypmed.2014.07.033

Rhodes, R. E., Janssen, I., Bredin, S. S. D., Warburton, D. E. R., and Bauman, A. (2017). Physical activity: health impact, prevalence, correlates and interventions. *Psychol. Health* 32, 942–975. doi: 10.1080/08870446.2017.1325486

Ridgers, N. D., Timperio, A., Ball, K., Lai, S. K., Brown, H., Macfarlane, S., et al. (2021). Effect of commercial wearables and digital behaviour change resources on the physical activity of adolescents attending schools in socio-economically disadvantaged areas: the RAW-PA cluster-randomised controlled trial. *Int. J. Behav. Nutr. Phys. Act.* 18:52. doi: 10.1186/s12966-021-01110-1

Ryan, R. M., and Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: definitions, theory, practices, and future directions. *Contemp. Educ. Psychol.* 61:101860. doi: 10.1016/j.cedpsych.2020.101860

Ryan, R. M., Deci, E. L., Vansteenkiste, M., and Soenens, B. (2021). Building a science of motivated persons: self-determination Theory's empirical approach to human experience and the regulation of behavior. *Motiv. Sci.* 7, 97–110. doi: 10.1037/mot0000194

Sánchez, J. M., and Núñez, J. L. (2007). Análisis preliminar de las propiedades psicométricas de la versión española de la escala de necesidades psicológicas básicas en el ejercicio físico. *Rev. Iberoam. Psicol. Ejerc. Deporte* 2, 83–92.

Sevil-Serrano, J., Aibar, A., Abós, Á., Generelo, E., and García-González, L. (2022). Improving motivation for physical activity and physical education through a school-based intervention. *J. Exp. Educ.* 90, 383–403. doi: 10.1080/00220973.2020.1764466

SHAPE America. (2013). *Grade-level outcomes for K-12 physical education*. Reston, VA: Author.

Slingerland, M., and Borghouts, L. (2011). Direct and indirect influence of physical education-based interventions on physical activity: a review. *J. Phys. Activit. Health* 8, 866–878. doi: 10.1123/jpah.8.6.866

Spieth, P. M., Kubasch, A. S., Penzlin, A. I., Illigens, B. M. W., Barlinn, K., and Siepmann, T. (2016). Randomized controlled trials - a matter of design. *Neuropsychiatr. Dis. Treat.* 12, 1341–1349. doi: 10.2147/ndt.s101938

Stefanou, C. R., Perencevich, K. C., DiCintio, M., and Turner, J. C. (2004). Supporting autonomy in the classroom: ways teachers encourage student decision making and ownership. *Educ. Psychol.* 39, 97–110. doi: 10.1207/s15326985ep3902_2

Stewart, A., Marfell-Jones, M., Olds, T., and De Ridder, J. (2011). *International standards for anthropometric assessment*. New Zealand: International Society for the Advancement of Kinanthropometry.

Teixeira, P. J., Carraça, E. V., Markland, D., Silva, M. N., and Ryan, R. M. (2012). Exercise, physical activity, and self-determination theory: a systematic review. *Int. J. Behav. Nutr. Phys. Act.* 9:78. doi: 10.1186/1479-5868-9-78

Teixeira, P. J., Marques, M. M., Silva, M. N., Brunet, J., Duda, J., Haerens, L., et al. (2020). Classification of techniques used in self-determination theory-based interventions in health contexts: an expert consensus study. *Motiv. Sci.* 6, 438–455. doi: 10.1037/mot0000172

Trigueros, R., Aguilar-Parra, J. M., Sánchez-Iglesias, A. I., González-Bernal, J. J., and Mercader, I. (2020). Adaptation and validation of the multi-dimensional perceived autonomy support scale for physical education to the Spanish physical exercise context. *Int. J. Environ. Res. Public Health* 17:3841. doi: 10.3390/ijerph17113841

Trigueros, R., Sicilia, A., Alcaraz-Ibáñez, M., and Dumitru, D. C. (2017). Spanish adaptation and validation of the revised perceived locus of causality scale in physical education. *Cuad. Psicol. Deporte* 17, 25–32.

Viciana, J., and Mayorga-Vega, D. (2016). Innovative teaching units applied to physical education – changing the curriculum management for authentic outcomes. *Kinesiology* 48, 142–152. doi: 10.26582/k.48.1.1

Viciana, J., Mayorga-Vega, D., Martínez-Baena, A., Hagger, M. S., Liukkonen, J., and Yli-Piipari, S. (2019). Effect of self-determined motivation in physical education on objectively measured habitual physical activity. *Kinesiology* 51, 141–149. doi: 10.26582/k.51.1.15

World Health Organization. (2018). *Global action plan on physical activity 2018–2030: More active people for a healthier world*. Geneva: World Health Organization.

World Health Organization. (2020). *Who guidelines on physical activity and sedentary behaviour*. Geneva: World Health Organization.

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Mediating effect of social interaction anxiety between emotional intelligence and life satisfaction in physical education students: post-COVID-19 study

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The aim of this research is to analyze the effect of social interaction anxiety on satisfaction with life mediated by emotional intelligence. The research design was descriptive, cross-sectional, and non-randomized. In total, 1,164 Mexican physical education students participated ($M_{age} = 21.21$; $SD = 3.26$; 30.0% female; 69.6% male; 0.4% other). The scales used were the Social Interaction Anxiety Scale, Trait Meta-Mood Scale and Satisfaction with Life and a structural equation analysis with latent variables was conducted. The results highlight that it can be asserted that emotional clarity and repair had a mediating effect between social interaction anxiety and satisfaction with life, as they did decrease the negative effects of social interaction anxiety on satisfaction with life. In addition, social interaction anxiety had a direct and positive effect on emotional attention and a negative effect on emotional clarity and repair.

KEYWORDS
social anxiety, emotional repair, emotional clarity, emotional attention, university

1. Introduction

The restrictive measures in response to the COVID-19 pandemic triggered serious consequences on the general health of the world's population (Faraci et al., 2022). The spread of the pandemic and the ensuing restrictive policies involving confinement, social distancing and mobility had a major impact on the global economy and the daily lives of people around the world (Di Crosta et al., 2020; Xiong et al., 2020; Gollwitzer et al., 2021; Kuo et al., 2021; Racine et al., 2022). These strategies came with severe negative psychological effects (Özdin and Bayrak Özdin, 2020; Pietrabissa and Simpson, 2020; Obschonka et al., 2021), including anxiety, depression, fear of illness, fear of death, fear of social interaction, post-traumatic stress and insomnia (Di Crosta et al., 2020; Rodríguez-Hidalgo et al., 2020; Torales et al., 2020; Sturgill et al., 2021). Said restrictive measures, meant to decrease community transmission (Weeden and Cornwell, 2020), even led to universities shutting down worldwide (Baños et al., 2022).

As a consequence of the COVID-19 pandemic, university education had to undergo a rapid transition from in-person classes to online learning systems (Baños et al., 2021). This increased the daily frequency of technology overuse among university students, especially smartphones

(Bhatnagar et al., 2021). This in turn amplified the irrational fear and stress experienced by middle school (Nguyen et al., 2022) and university students (Zwilling, 2022) of being away from a device that facilitates both general communication and attending academic activities, especially in students who struggle to regulate their emotions (Ercengiz et al., 2020; Brown and Medcalf-Bell, 2022). Thus, COVID-19 not only comes with a dreadful pathology, but it is also the source of numerous secondary problems, such as becoming addicted to the use of the Internet, social networks and any form of media associated with recent technologies (Masrek et al., 2022). In fact, the disruptive use of smartphones surged from the onset of the first wave of COVID-19 (Zwilling, 2022), thereby increasing the incidence of pathologies such as stress and anxiety (Nguyen et al., 2022), which even doubled in some countries during the first confinement period (Amerio et al., 2021; Medda et al., 2022). Therefore, as the amount of time spent on screens (e.g., smartphones, computers, tablets, etc.) increases, physical interaction among people diminishes, which has an impact on their social interaction skills (Masrek et al., 2022). For all these reasons, it would be interesting to determine if the levels of social interaction anxiety (SIA) among students can affect their satisfaction with life once the confinement and social distancing measures are lifted and on-site classes return in a post-pandemic context. Despite the significance that the students' emotional regulation can have in this situation, few studies have analyzed the effect of SIA on satisfaction with life taking into account the emotional intelligence of the students once they have returned to in-person classes at universities following the end of confinement.

1.1. Social interaction anxiety

SIA refers to intense, individual emotional reactions and avoidance behaviors, such as fear, anxiety and distress regarding one or multiple social interactions (Li, 2020). SIA is a widespread condition that can sometimes become chronic, causing severe impact on a person's academic, occupational and social functioning, as well as their psychological well-being on a general level (Wittchen et al., 2000; Kessler, 2003; O'Toole et al., 2013). The fear of being judged or negatively criticized is the core motive that, together with the fear of contracting COVID-19, prompted people to avoid social interactions, which in turn affected the individuals' daily functioning (Erliksson et al., 2020). Not addressing this pathology immediately and otherwise allowing it to develop in young people may lead to detrimental effects on their mental health and undermine their academic work and their lives in general (Chartrand et al., 2011). As previously mentioned, social interaction was rare or even non-existent during the pandemic, which could easily trigger SIA and unhealthy emotions, especially in young students who continued their education at home (Hahn, 2020). As age increases, so do the academic load and pressure put on young people, which can lead to an increase in interpersonal communication problems; therefore, the social environment can become overwhelming, leading to psychological conditions common in contemporary youth (Li, 2020). This can be particularly detrimental to students about to graduate, as their interpersonal environment has grown increasingly complex and they may become anxious more easily when facing interpersonal problems (Kwon et al., 2018).

People with high levels of SIA exhibit low self-esteem, depressive symptoms and increased dissatisfaction with life (Makadi and Koszycki, 2020). SIA has also been related to obsessive-compulsive disorders, depression and generalized anxiety disorder (Erliksson et al., 2020). A major characteristic of people with SIA is a lack of emotional regulation (Kashdan and Steger, 2006; Kashdan and Breen, 2008; Werner et al., 2011). Therefore, acknowledging or understanding emotions may play a significant role in the adaptive regulation of emotions during social interactions that cause the person to become anxious (O'Toole et al., 2013).

1.2. Emotional intelligence

In the university context, emotional intelligence has been highlighted as an adequate tool for coping with stressful situations and achieving successful academic performance and emotional well-being (Parhiala et al., 2018; Guil et al., 2021). Emotional intelligence is defined as an individual's ability to assess and regulate their own emotions and use them to solve problems and accomplish goals (Salovey et al., 1995). Guil et al. (2021) propose that emotional intelligence is composed of three dimensions: emotional attention (i.e., self-perceptions about the degree to which an individual addresses their own emotional experiences), emotional clarity (i.e., self-perceptions regarding how clearly people understand emotional states) and emotional repair (i.e., self-perceptions about the ability to adequately manage emotions). In general, research has found that higher scores on emotional intelligence are associated with better psychological functioning and well-being, whereas low scores are linked to anxiety (Berenbaum et al., 2003; García-Fernández et al., 2015). Likewise, there are individual differences in the degree of the three dimensions (attention, clarity and repair), with each dimension having a different role (García-Fernández et al., 2015). Enhancing our understanding of broad emotional constructs and discrete emotions in SAD can have implications for theoretical models of SAD, for clinical assessment and diagnosis, and for treatment (Rozen and Aderka, 2023). Numerous authors have suggested further research on how these three dimensions interact and their relationship with SIA (Turk et al., 2005; Boden and Berenbaum, 2012; García-Fernández et al., 2015; Guil et al., 2019).

In this vein, the predisposition of SIA increases when one does not pay attention to the information that emotions provide or possesses high emotional attention but poor emotional clarity (Boden and Berenbaum, 2012). The role of emotional attention is less clear than those of emotional repair and clarity (García-Fernández et al., 2015). On the one hand, although individuals must pay at least some attention to their emotions in order to understand them and to remediate negative ones, high levels of attention have been found to be detrimental to emotional well-being (Salovey et al., 1995). On the other hand, emotional attention has been negatively related to SIA (Turk et al., 2005; Guil et al., 2019). As can be seen, there is controversy regarding the relationship between SIA and the dimension of emotional attention.

Because the ability to clearly identify one's emotions is the first step to successful emotional regulation and coping (Butler et al., 2006), the importance of emotional clarity in regulating emotions has been particularly underscored. In this case, as opposed to the dimension of emotional attention, most studies agree that a lack of emotional clarity greatly increases SIA (Dixon-Gordon et al., 2014; Thompson et al., 2017; Butler et al., 2018; Guil et al., 2019).

Likewise, individuals with lower levels of emotional clarity tend to describe more paranoid beliefs (Boden and Berenbaum, 2012). O'Toole et al. (2013) suggest that deficits in emotional clarity and difficulties in remediating negative emotions are key factors to consider when addressing SIA. In fact, several studies have negatively related emotional repair to SIA (Bigman et al., 2015; Klemanski et al., 2017; Guil et al., 2019; Masters et al., 2019). Specifically in the university context, it has been found that students who hoped to be more successful in regulating their negative emotions showed fewer signs of anxiety (Catanzaro and Mearns, 1999). Furthermore, middle school students who exhibited higher levels of emotional intelligence during the pandemic scored higher on satisfaction with life (Correa-Barwick et al., 2022; Torres-Gázquez et al., 2023). Along these lines, Sturgill et al. (2021) found that a Mindfulness program with university students increased their emotional intelligence and satisfaction with life, however, studies on this population conducted during the pandemic are scarce.

1.3. Psychological well-being

The concept of psychological well-being is closely linked to the subjective well-being and the quality of life or satisfaction with life (SWL) concepts (Baños et al., 2019). Diener and Emmons (1985) postulated the Subjective Well-Being Theory to analyze people's SWL, defining "subjective well-being" as the subjective assessment of one's own life quality, that is, the range of elements from transitory stages to relatively abstract assessments or evaluations of the meaning of one's life. These authors stated that people can express being satisfied with their lives either from a global evaluation or after making different assessments in specific areas of their lives (e.g., family, work, social relationships, etc.; Diener and Emmons, 1985). Several studies have associated SWL with low levels of SIA (Wittchen et al., 2000; Kessler, 2003; O'Toole et al., 2013) and with high levels of emotional intelligence (Hodzic et al., 2016; Sánchez-Álvarez et al., 2016; Blasco-Belled et al., 2020).

In terms of the dimensions of emotional intelligence, a study conducted in Spain, Portugal and Brazil found that SWL was predicted by emotional clarity and emotional repair, but not by emotional attention (Hodzic et al., 2016). Blasco-Belled et al. (2020) also found that emotional attention was negatively related to subjective well-being, albeit this relationship was not significant in the study conducted by Ramos-Díaz et al. (2019). In this line, it is emphasized that a decrease in emotional attention and an increase in emotional clarity and repair should be the target of interventions in adolescents to improve their SWL (Guerra-Bustamante et al., 2019; Martínez-Marín and Martínez, 2019; Azpiazu et al., 2022; De la Barrera et al., 2023), since the intelligent management of emotions helps to prevent negative feelings and fosters positive ones, thus promoting greater SWL (Sánchez-Álvarez et al., 2016). Several studies have highlighted the importance of emotional clarity and repair for improved psychological functioning (Petrides et al., 2018; Masters et al., 2019), psychological adjustment (Salguero et al., 2012; García-Fernández et al., 2015; Butler et al., 2018) and psychological well-being (Gohm and Clore, 2002; Extremera and Fernández, 2005; Salguero et al., 2012).

1.4. The present study

After analyzing the scientific literature and observing the importance of emotional clarity and repair in preventing SIA and improving people's SWL, both before and during the COVID-19 pandemic, the predictive analysis of SIA and emotional intelligence on SWL can be deemed relevant, understood that the sanitary restrictions have been lifted. In summary, on the one hand, studies have related SIA to emotional intelligence (Parhiala et al., 2018; Guil et al., 2021) and SIA to satisfaction with life (Wittchen et al., 2000; Kessler, 2003; O'Toole et al., 2013), and, on the other hand, emotional intelligence to satisfaction with life (Hodzic et al., 2016; Sánchez-Álvarez et al., 2016; Blasco-Belled et al., 2020). All these studies were conducted before or during the pandemic, however, we are unaware of the existence of studies that have analyzed emotional intelligence as a mediating variable between SIA and SWL, and if the relationships between these variables have been analyzed following the end of mobility restrictions and the return to in-person university classes. Moreover, research conducted with Mexican students was scarce even before the pandemic. Therefore, this study represents a contribution to the understanding of the relationships among SIA, the dimensions of emotional intelligence and SWL in the Mexican university context. Thus, the objective of this research is to analyze the effect of SIA on SWL mediated by emotional intelligence. Figure 1 shows the hypothesized model for examining the relationships described above. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) initiative (Von Elm et al., 2008).

2. Materials and methods

2.1. Design and participants

The research design was descriptive, cross-sectional, observational and non-randomized. The sample was composed of students from the Faculty of Sport of the three campuses (Campus Ensenada, Campus Mexicali and Campus Tijuana) of the Autonomous University of Baja California (Mexico). Inclusion criteria were the following: (i) to be enrolled in the Bachelor's degree in Physical Activity and Sport at the aforementioned campus and university; exclusion criteria: (i) failure to provide their informed consent for data use in the study; (ii) failure to duly fill out the data collection form. An *a priori* analysis of the necessary sampling size was conducted to provide an answer to the study objective, considering a structural equation model (SEM) composed of five latent variables and 53 observable variables. The analysis was conducted using the *Free Statistics Calculator* v.4.0 software (Soper, 2023) and a minimum of 1,151 participants was calculated to detect effect sizes (f^2) = 0.163, with a statistical power of 0.99% and a significance level of α = 0.05. In this research 1,164 physical education students (30.0% women; 69.6% men; 0.4% other) from the three campuses of the Faculty of Sports of the Autonomous University of Baja California (19.8%, Campus Ensenada; 30.7%, Campus Tijuana; 49.6%, Campus Tijuana) participated, aged between 17 and 50 years old (M = 21.21; SD = 3.26). There were no lost values in the responses included in the study. Apart from the total sample, 29 questionnaires were discarded because they were filled incorrectly, and 14 because the respondents did not give their consent to participate in the research.

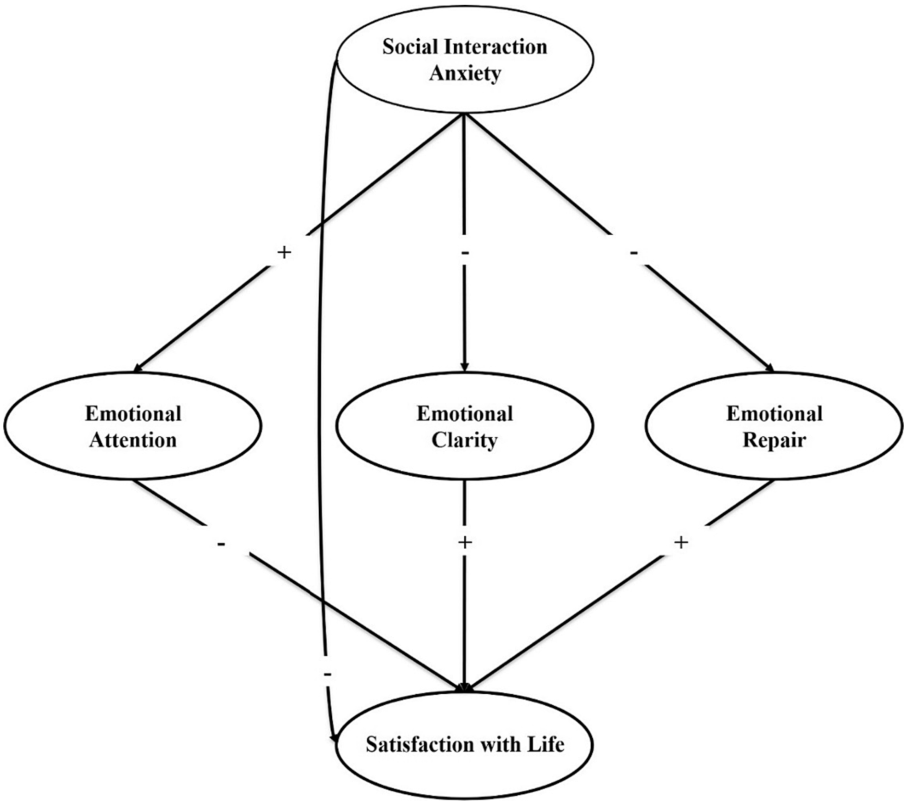

FIGURE 1
Hypothesized model with the expected correlations.

2.2. Instruments

2.2.1. Interaction Anxiety Scale

This study used the scale adapted to the Mexican context by de la Rubia et al. (2013) based on the original version by Mattick and Clarke (1998). This instrument is composed of 20 items that measure social interaction anxiety (e.g., I find it hard to socialize with my classmates. "*Se me hace difícil socializar con las personas con las que estudio*"). Answers were collected using a 5-point Likert scale ranging from 0 (*not at all*) to 4 (*completely*). For this study, the CFA (Confirmatory Factorial Analysis) goodness-of-fit indices were acceptable: χ^2/df = 5.01, p < 0.001; CFI = 0.98; TLI = 0.98; RMSEA = 0.059 (90%CI = 0.047, 0.070; p_{close} = 0.077), SRMR = 0.033.

2.2.2. Emotional intelligence

This study used the Mexican version by Valdivia et al. (2015) adapted from the original version by Salovey et al. (1995). The scale contains 28 items that measure emotional intelligence across three dimensions: *emotional attention* (8 items; e.g., I frequently think about my feelings. "*A menudo pienso en mis sentimientos*"), *emotional clarity* (8 items; e.g., I am capable of understanding my feelings. "*Puedo llegar a comprender mis sentimientos*"), and *emotional repair* (8 items; e.g., When I feel sad, I think about all the pleasures in life. "*Cuando estoy triste, pienso en todos los placeres de la vida*"). Answers were collected using a Likert scale ranging from 1 (*completely disagree*) to 5 (*completely agree*). For this study, the CFA goodness-of-fit indices were acceptable: χ^2/gl = 4.97, p < 0.001; CFI = 0.98; TLI = 0.97; RMSEA = 0.058 (90%CI = 0.046, 0.068; p_{close} = 0.072), SRMR = 0.042.

2.2.3. Satisfaction with life

This study used the scale adapted into Spanish by Atienza et al. (2000) to measure satisfaction with life in general based on the original version by Diener and Emmons (1985). The scale contains 5 grouped items that measure satisfaction with life (e.g., My life circumstances are good. "*Las circunstancias de mi vida son buenas*"). Answers were collected using a Likert scale ranging from 1 (*completely disagree*) to 5 (*completely agree*). For this study, the CFA goodness-of-fit indices were acceptable: χ^2/gl = 2.55, p = 0.054; CFI = 0.99; TLI = 0.99; RMSEA = 0.037 (90%CI = 0.000, 0.070; p_{close} = 0.071), SRMR = 0.011.

2.3. Procedure

First, a meeting was held with the three deputy directors and the general director of the Faculty of Sports of the three campuses of the Autonomous University of Baja California (Ensenada, Mexicali and Tijuana). The purpose of the study was explained and permission to apply the questionnaires was requested. Upon granted authorization, the participants were summoned to the institution's computer room in March 2022. Participants were taught how to fill out the online questionnaires and informed about the importance of the research, that their participation was anonymous, and that there were no right or wrong answers; they were thus asked to be completely honest and were told that they could abandon the study at any time if they desired so. The questionnaire was completed in around 20 min and all participants gave their prior consent for their responses to be included in the study. The research protocol was approved by the Bioethics Committee of the University of Almeria (Ref: UALBIO2023/001).

2.4. Statistical analysis

A structural equation model (SEM) with latent variables was carried out to analyze how SIA is associated with emotional intelligence and satisfaction with life in Mexican university students. For the SEM, a two-step method following Kline (2016) was developed. In step-1, bidirectional relationships between variables were evaluated (i.e., measurement model). In step-2, the predictive effects between the variables were assessed. The SEM was controlled by the variable sex and campus of origin. The following indices were used to evaluate the models: chi square/degrees of freedom (χ^2/df), CFI (Comparative Fit Index), TLI (Tucker–Lewis Index), RMSEA (Root Mean Square Error of Approximation) with a confidence interval of 90% (CI), and SRMR (Standardized Root Mean Square Residual). For the χ^2/gl ratio, values <2.0 or <5.0 are, respectively, considered excellent (Tabachnick and Fidell, 2019) or acceptable (Hu and Bentler, 1999); for the CFI and TLI, values >0.95 are considered excellent, whereas the range between 0.90 and 0.95 is considered acceptable; for the RMSEA and SRME, values <0.06 are considered excellent, and <0.08, acceptable (Hu and Bentler, 1999; Marsh et al., 2004) Due to the lack of multivariate normality in the SEM (Mardia's coefficient = 106.82; $p < 0.001$) the maximum likelihood (ML) method was used with the *bootstrapping* procedure for 5,000 re-samplings (Kline, 2016). The reliability of each scale was assessed using different parameters: McDonald's omega (ω), composite reliability (CR), and AVE for measuring convergent validity. Reliability values >0.70 and AVE > 0.50 are deemed acceptable. For this study, even if the SWL scale yields an AVE value <0.50 (i.e., 0.47), such value is deemed acceptable according to Hair et al. (2018), as all the standardized regression weights were significant and >0.50.

3. Results

3.1. Preliminary results

Descriptive statistics and correlations between the different variables are shown in Table 1.

3.2. Main results

During step 1, the SEM showed excellent goodness-of-fit indices: χ^2/gl = 2.40, $p < 0.001$; CFI = 0.98; TLI = 0.97; RMSEA = 0.035(90%CI = 0.031; 0.038; p_{close} = 1.00), SRMR = 0.035. During step 2, the hypothesized SEM yielded a similar and excellent fit: χ^2/gl = 2.40, $p < 0.001$; CFI = 0.98; TLI = 0.97; RMSEA = 0.035(90%CI = 0.031; 0.038; p_{close} = 1.000), SRMR = 0.035. The model was controlled by the sex and campus of origin variable and reached an explained variance of 31% for SWL, 3% for emotional attention, 4% for emotional repair and 10% for emotional clarity (Figure 2). The correlations among SIA, the emotional intelligence variables (i.e., emotional attention, emotional clarity, and emotional repair) and SWL can be attested in Figure 2 and Table 2.

Figure 2 outlines the SEM and shows that SIA has a direct, negative and significant relationship with SWL ($p < 0.001$), as well as emotional clarity ($p < 0.00$) and emotional repair ($p < 0.001$). On the other hand, SIA has a direct, positive and significant relationship with emotional attention ($p = 0.004$). In terms of the mediating effect of the dimensions of emotional intelligence, it should be noted that emotional clarity and emotional repair play a remarkable role between SIA and SWL, as they soften the negative direct effect of SIA on SWL, given that these two dimensions (i.e., emotional clarity and emotional repair) have a positive and significant direct effect on SWL (Table 2). In addition, Figure 2 demonstrates the CI (95%) of R^2, thereby confirming that these values can be considered ES measurements (Dominguez-Lara, 2017).

4. Discussion

The purpose of this research was to analyze emotional intelligence as a mediator between SIA and SWL. The main results illustrate the important role of emotional clarity and repair as mediating variables between SIA and SWL, given that they decrease the negative effect of SIA on SWL.

A possible explanation for this is that emotional clarity is the key to regulating emotions, as the ability to clearly identify one's emotions is the first step to successful emotional regulation and coping (Butler et al., 2006). Thus, young people who understand their emotions and recognize their own abilities to solve problems and overcome difficult situations through their own efforts will adopt a positive emotional coping style, mitigating the distress caused by SIA and improving their social performance (Li, 2020), and thus their SWL (Hodzic et al., 2016). In this vein, Guil et al. (2019) highlight the importance of the interaction between the three dimensions of emotional intelligence concerning SIA. These authors state that students who are confident in their own abilities to cope with challenging situations, do not pay much attention to their emotions, and do trust their competencies to clearly perceive and repair their emotional states will cope more efficiently with SIA (Guil et al., 2019). In terms of the relationship of SIA with the dimensions of emotional intelligence, we consider that, because of its timely execution, this study provides the global university context with an important scientific contribution, understanding that the data for the present study were collected just 2 weeks after the return to in-person classes following the COVID-19 confinement, as the fear of contagion and stress in general due to the pandemic were still visible in society (Di Crosta et al., 2020; Rodríguez-Hidalgo et al., 2020; Torales et al., 2020).

However, according to our research, emotional attention did not have a significant direct effect on SWL, nor were there significant indirect effects between SIA and SWL. In this line, Hodzic et al. (2016) also did not obtain a significant relationship between emotional attention and SWL. Although the role of emotional attention compared to emotional clarity and repair is confusing according to García-Fernández et al. (2015), on the one hand, Blasco-Belled et al. (2020) have found that emotional attention negatively and significantly predicts SWL (Blasco-Belled et al., 2020), while others found a negative but not significant prediction (Hodzic et al., 2016;

TABLE 1 Descriptive statistics and correlations among variables.

Variable	Range	M	SD	Q1	Q2	ω	CR	AVE	2	3	4	5
1. Emotional attention	1–5	3.47	1.10	−0.35	−0.65	0.89	0.89	0.67	0.21**	0.08**	0.08**	0.05
2. Emotional clarity	1–5	3.43	1.05	−0.30	−0.58	0.90	0.82	0.60	-	0.33**	−0.27**	0.37**
3. Emotional repair	1–5	3.76	1.03	−0.64	−0.26	0.85	0.87	0.69		-	−0.16**	0.37**
4. Social interaction anxiety	0–4	1.47	1.05	0.39	−0.76	0.93	0.90	0.54			-	−0.29**
5. Satisfaction with life	1–5	3.67	0.84	−0.44	−0.26	0.81	0.81	0.47				-

M = mean; SD = standard deviation; Q1 = skewness; Q2 = kurtosis; ω = omega of McDonald; CR = composite reliability; AVE = average variance extracted.
*Correlation is significant at level 0.05. **Correlation is significant at level 0.01.

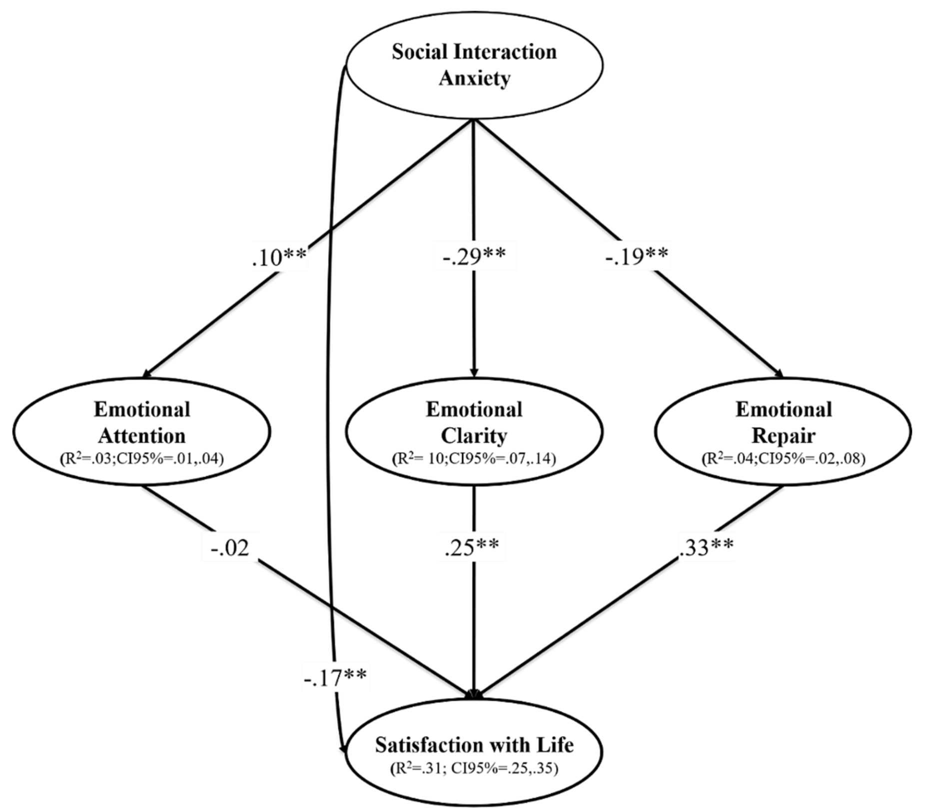

FIGURE 2
Predictive relationships of the emotional intelligence on satisfaction with life through the mediating role of the social interaction anxiety. **$p < 0.01$; *$p < 0.05$. R^2 = Explained variance; CI = Confidence interval. The dashed lines represent non-significant relationships. The model was controlled by the sex and the campus of the students.

Ramos-Díaz et al., 2019). Emotional attention not predicting SWL could be due to the fact that this dimension does not have as much of a potential inference in people's behavior as emotional clarity and emotional repair do (Salovey et al., 1995). Thus, when students pay too much attention to their emotions without understanding them or having repair skills, they negatively affect their mood and psychological functioning (García-Fernández et al., 2015; Butler et al., 2018; Petrides et al., 2018; Masters et al., 2019), while also decreasing their SWL (Guerra-Bustamante et al., 2019; Martínez-Marín and Martínez, 2019; Azpiazu et al., 2022; De la Barrera et al., 2023). On the contrary, the intelligent management of emotions helps students to prevent negative feelings and increases positive ones, contributing to the increase of SWL (Sánchez-Álvarez et al., 2016) while improving academic performance with appropriate learning strategies (García-Fernández et al., 2015). Because scientific literature in this context is scarce, and given that the results obtained are in line with the international literature, we consider this study to be a scientific contribution to the Mexican university context.

It is also worth mentioning that SIA significantly, positively and directly predicted emotional attention in this research. Since past studies have negatively related SIA to emotional attention (Turk et al., 2005; Guil et al., 2019), contrary to the results obtained in this research, the relationship between SIA and emotional attention remains controversial (García-Fernández et al., 2015). However, the results obtained in the present study are in line with the findings of Boden and Berenbaum (2012), who also described a positive relationship between SIA and emotional attention. These authors claim that when one does not pay attention to the information

TABLE 2 Estimation of significant standardized parameters and statistics of the mediation model.

	Independent variable	Dependent variable	Mediator	β	SE	95%CI	
						Inf	Sup
Direct effects							
	SIA	Emotional attention		0.10**	0.04	0.03	0.16
	SIA	Emotional clarity		−0.29**	0.04	−0.35	−0.23
	SIA	Emotional repair		−0.19**	0.03	−0.24	−0.13
	SIA	SWL		−0.17**	0.04	−0.22	−0.11
	Emotional clarity	SWL		0.25**	0.05	0.17	0.33
	Emotional repair	SWL		0.33**	0.04	0.25	0.40
Indirect effects							
	SIA	SWL	Emotional Clarity	−0.07**	0.01	−0.09	−0.04
	SIA	SWL	Emotional Repair	−0.06**	0.01	−0.07	−0.03
Total effects							
	SIA	SWL		−0.30**	0.03	−0.36	−0.24

β = Estimation of standardized parameters; SE = standard error; 95% CI = 95% confidence interval; Inf = Inferior limit of 95% CI; Sup = Superior limit of 95% CI. SIA = social interaction anxiety; SWL = satisfaction with life.
*$p < 0.05$. **$p < 0.01$.

provided by emotions, or one has a high level of emotional attention, but with a deficient emotional clarity, the predisposition toward SIA increases. A potential explanation is that people with a high level of emotional attention tend to be hypervigilant about their own emotions and signs of anxiety, becoming less flexible to explain their states of anxiety and misjudging both their severity and visibility to others, and feeling more threatened by how others understand them (Roth et al., 2001; Wells and Papageorgiou, 2001; Edelmann and Baker, 2002).

Finally, we will describe a series of limitations and strengths of the present study, as well as future research perspectives. Limitations include: (i) the timing of data collection, 2 weeks after the confinement and mobility measures due to the COVID-19 pandemic had been lifted, as this might have caused widespread emotional and psychological instability in participants, even when filling the questionnaires; (ii) the variables were evaluated neither before nor during the pandemic, so we are not able to observe the evolution of these variables after such an upsetting experience; (iii) the cross-sectional design of the study does not allow for establishing causal inferences; (iv) there was no sample randomization, so the results cannot be generalized; (v) a possible social desirability bias due to the use of self-reporting, since participants may have exaggerated their responses. On the other hand, noteworthy strengths of this research include: (i) the timing of data collection may be a strength in itself since scientific literature on this topic set just after the end of mobility restrictions is scarce; (ii) the sample size of Mexican undergraduate Physical Education students from the three campuses of the Autonomous University of Baja California (Ensenada, Tijuana and Mexicali), as well as the statistical power of the study. We consider it necessary for future studies to analyze the dimension of emotional attention by conducting a quadratic regression analysis since both excessive emotional attention and low levels of this dimension are related to SIA. We also suggest longitudinal studies a few years after the pandemic to analyze how the post-pandemic dimensions of emotional intelligence relate to occupational success.

5. Conclusion

In conclusion, it can be asserted that emotional clarity and repair had a mediating effect between SIA and SWL, as they did decrease the negative effects of SIA on SWL. In addition, SIA had a direct and positive effect on emotional attention and a negative effect on emotional clarity and repair. Furthermore, emotional clarity and repair had a direct and positive effect on SWL, although emotional attention did not predict SWL. Therefore, we believe that university institutions should train and educate students in managing SIA by further developing their emotional intelligence. It would be interesting to provide university students with strategies to control and manage the understanding of their own emotions, and to manage negative emotions resulting from SIA. Finally, it is important to highlight the importance of young people not paying too much emotional attention, as an excess of it can increase SIA levels, undermining SWL at the same time.

6. Practical implications

The results of this research underline the importance of emotional clarity and repair in decreasing SIA and increasing SWL in Mexican university students after the pandemic and are in line with other studies conducted before the pandemic. Therefore, educational institutions should organize workshops related to the development of emotional intelligence to help young people to understand the feelings and emotions that they experience, and to remediate negative emotions that might be stressful for them (Correa-Barwick et al., 2022; Cabello-Sanz and Muñoz-Parreño, 2023; Torres-Gázquez et al., 2023). In this line, Valenti et al. (2022) consider that appropriate programs should be designed to help people to see the bright side of negative experiences, which permits a reshaping of harmful emotional outcomes by focusing on some positive aspects. In addition, it is recommended that people suffering from SIA practice activities such as Mindfulness (Butler et al., 2018), aerobic exercise (Jazaieri et al., 2012), or activities in natural environments (Chen and Huo, 2022), as they help to decrease SIA and to increase the levels of SWL.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the University of Almería (Ref: UALBIO2023/001). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JC-N: Conceptualization, Data curation, Formal analysis, Writing – review & editing. AG-G: Conceptualization, Formal analysis, Methodology, Writing – review & editing. RE-G: Data curation, Investigation, Writing – review & editing. RB: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Amerio, A., Lugo, A., Stival, C., Fanucchi, T., Gorini, G., Pacifici, R., et al. (2021). COVID-19 lockdown impact on mental health in a large representative sample of Italian adults. *J. Affect. Disord.* 292, 398–404. doi: 10.1016/j.jad.2021.05.117

Atienza, F. L., Pons, D., Balaguer, I., and García-Merita, M. (2000). Propiedades psicométricas de la Escala de Satisfacción con la Vida en adolescentes. *Psicothema* 12, 314–319.

Azpiazu, L., Fernández-Zabala, A., Rodríguez-Fernández, A., and Ramos-Díaz, E. (2022). Perceived emotional intelligence and subjective well-being during adolescence: the moderating effect of age and sex. *Curr. Psychol.* doi: 10.1007/s12144-022-04128-1

Baños, R., Barretos-Ruvalcaba, M., and Baena-Extremera, A. (2019). Protocol for the study of the academic, psychological and physical activity variables that influence the academic performance of Mexican and Spanish adolescents. *Espiral* 12, 89–99. doi: 10.25115/ecp.v12i25.2480

Baños, R., Morán-Navarro, R., Toval, Á., Del Lidón López-Iborra, M., Morales-Delgado, N., and Ferrán, J. L. (2022). Learning and evaluation of human anatomy content in sports sciences through surf videos. *Espiral* 15, 1–10. doi: 10.25115/ecp.v15i30.5767

Baños, R., Toval, Á., Morales-Delgado, N., and Luis Ferrán, J. (2021). Analysis of movement during climbing as a strategy for learning the anatomy of the locomotor system in sport sciences. *Espiral* 14, 102–112. doi: 10.25115/ecp.v14i29.4540

Berenbaum, H., Raghavan, C., Le, H. N., Vernon, L. L., and Gomez, J. J. (2003). A taxonomy of emotional disturbances. *Clin. Psychol. Sci. Pract.* 10, 206–226. doi: 10.1093/clipsy/bpg011

Bhatnagar, A., Khanna, U., and Rana, A. (2021). Digital learning ecosystem at Indian higher education system. *J. Contemp. Iss. Bus. Gov.* 27, 4360–4375. Available at: https://www.cibgp.com/issue-content/digital-learning-ecosystem-at-indian-higher-education-system-2399

Bigman, Y. E., Mauss, I. B., Gross, J. J., and Tamir, M. (2015). Yes I can: expected success promotes actual success in emotion regulation. *Cognit. Emot.* 30, 1380–1387. doi: 10.1080/02699931.2015.1067188

Blasco-Belled, A., Rogoza, R., Torrelles-Nadal, C., and Alsinet, C. (2020). Emotional intelligence structure and its relationship with life satisfaction and happiness: new findings from the Bifactor model. *J. Happiness Stud.* 21, 2031–2049. doi: 10.1007/s10902-019-00167-x

Boden, M. T., and Berenbaum, H. (2012). Facets of emotional clarity and suspiciousness. *Pers. Individ. Differ.* 53, 426–430. doi: 10.1016/j.paid.2012.04.010

Brown, G., and Medcalf-Bell, R. (2022). Phoning it in: social anxiety, intolerance of uncertainty, and anxiety reduction motivations predict phone use in social situations. *Hum. Behav. Emerg. Tech.* 2022, 1–8. doi: 10.1155/2022/6153053

Butler, R. M., Boden, M. T., Olino, T. M., Morrison, A. S., Goldin, P. R., Gross, J. J., et al. (2018). Emotional clarity and attention to emotions in cognitive behavioral group therapy and mindfulness-based stress reduction for social anxiety disorder. *J. Anxiety Disord.* 55, 31–38. doi: 10.1016/j.janxdis.2018.03.003

Butler, E. A., Wilhelm, F. H., and Gross, J. J. (2006). Respiratory sinus arrhythmia, emotion, and emotion regulation during social interaction. *Psychophysiology* 43, 612–622. doi: 10.1111/j.1469-8986.2006.00467.x

Cabello-Sanz, S., and Muñoz-Parreño, J. A. (2023). Design, implementation, and evaluation of the "Universo Emocionante" emotional educational program through the service-learning methodology. *Espiral* 16, 95–105. doi: 10.25115/ecp.v16i32.8754

Catanzaro, S. J., and Mearns, J. (1999). "Mood-related expectancy, emotional experience, and coping behavior" in *How expectancies shape experience*. ed. I. Kirsch (Washington DC, United States: American Psychological Association), 67–91.

Chartrand, H., Cox, B., El-Gabalawy, R., and Clara, I. (2011). Social anxiety disorder subtypes and their mental health correlates in a nationally representative Canadian sample. *Can. J. Behav. Sci.-Rev. Can. Sci. Comport.* 43, 89–98. doi: 10.1037/a0022435

Chen, Y., and Huo, Y. (2022). Social interaction anxiety and problematic smartphone use among rural-urban adolescents in China: a moderated moderated-mediation model. *Youth Soc.* 55, 686–707. doi: 10.1177/0044118X221126548

Correa-Barwick, G. S., Carrasco-Poyatos, M., and Molina-Fernández, J. D. (2022). Emotional intelligence and satisfaction with life in schoolchildren during times of pandemic. *Espiral* 15, 57–70.

De la Barrera, U., Villanueva, L., Montoya-Castilla, I., and Prado-Gascó, V. (2023). How much emotional attention is appropriate? The influence of emotional intelligence and subjective well-being on adolescents' stress. *Curr. Psychol.* 42, 5131–5143. doi: 10.1007/s12144-021-01763-y

de la Rubia, J. M., Cadena, C. H. G., and Casas, C. J. A. (2013). Validación de la escala de ansiedad en la interacción social en estudiantes universitarios mexicanos. *Pensamiento Psicol.* 11, 27–42. Available at: https://www.redalyc.org/articulo.oa?id=80127000001

Di Crosta, A., Palumbo, R., Marchetti, D., Ceccato, I., La Malva, P., Maiella, R., et al. (2020). Individual differences, economic stability, and fear of contagion as risk factors for PTSD symptoms in the COVID-19 emergency. *Front. Psychol.* 11:567367. doi: 10.3389/fpsyg.2020.567367

Diener, E., and Emmons, R. A. (1985). The independence of positive and negative affect. *J. Pers. Assess.* 99, 91–95.

Dixon-Gordon, K., Dovidio, J., Gilbert, K., Hilt, L., Marroquin, B., Mclaughlin, K., et al. (2014). Impaired emotional clarity and psychopathology: a transdiagnostic deficit with symptom-specific pathways through emotion regulation. *J. Soc. Clin. Psychol.* 33, 319–342. doi: 10.1521/jscp.2014.33.4.319

Dominguez-Lara, S. (2017). Magnitud del efecto en análisis de regresión. *Interacciones* 3, 3–5. doi: 10.24016/2017.v3n1.46

Edelmann, R. J., and Baker, S. R. (2002). Self-reported and actual physiological responses in social phobia. *Br. J. Clin. Psychol.* 41, 1–14. doi: 10.1348/014466502163732

Ercengiz, M., Yildiz, B., Savci, M., and Griffiths, M. D. (2020). Differentiation of self, emotion management skills, and nomophobia among smartphone users: the mediating and moderating roles of intolerance of uncertainty. *Soc. Sci. J.*, 1–15. doi: 10.1080/03623319.2020.1833148

Erliksson, O. J., Lindner, P., and Mörtberg, E. (2020). Measuring associations between social anxiety and use of different types of social media using the Swedish social anxiety scale for social media users: a psychometric evaluation and cross-sectional study. *Scand. J. Psychol.* 61, 819–826. doi: 10.1111/sjop.12673

Extremera, N., and Fernández, P. (2005). Inteligencia emocional percibida y diferencias individuales en el meta-conocimiento de los estados emocionales: Una revisión de los estudios con el TMMS. *Ansiedad Estres* 11, 101–122. Available at: https://www.ansiedadyestres.es/ref/2005/11-101-122

Faraci, P., Bottaro, R., Valenti, G. D., and Craparo, G. (2022). Psychological well-being during the second wave of COVID-19 pandemic: the mediation role of generalized anxiety. *Psychol. Res. Behav. Manag.* 15, 695–709. doi: 10.2147/PRBM.S354083

García-Fernández, J. M., Inglés, C. J., Suriá, R., Martín, N. L. S., Gonzálvez-Maciá, C., Aparisi, D., et al. (2015). Profiles of emotional intelligence and learning strategies in a sample of Chilean students. *Eur. J. Psychol. Educ.* 30, 437–455. doi: 10.1007/s10212-015-0254-9

Gohm, C. L., and Clore, G. L. (2002). Four latent traits of emotional experience and their involvement in well-being, coping, and attributional style. *Cognit. Emot.* 16, 495–518. doi: 10.1080/02699930143000374

Gollwitzer, M., Platzer, C., Zwarg, C., and Göritz, A. S. (2021). Public acceptance of Covid-19 lockdown scenarios. *Int. J. Psychol.* 56, 551–565. doi: 10.1002/ijop.12721

Guerra-Bustamante, J., León-Del-Barco, B., Yuste-Tosina, R., López-Ramos, V. M., and Mendo-Lázaro, S. (2019). Emotional intelligence and psychological well-being in adolescents. *Int. J. Environ. Res. Public Health* 16:1720. doi: 10.3390/ijerph16101720

Guil, R., Gómez-Molinero, R., Merchán-Clavellino, A., and Gil-Olarte, P. (2021). Lights and shadows of trait emotional intelligence: its mediating role in the relationship between negative affect and state anxiety in university students. *Front. Psychol.* 11:615010. doi: 10.3389/fpsyg.2020.615010

Guil, R., Gómez-Molinero, R., Merchan-Clavellino, A., Gil-Olarte, P., and Zayas, A. (2019). Facing anxiety, growing up. Trait emotional intelligence as a mediator of the relationship between self-esteem and university anxiety. *Front. Psychol.* 10:567. doi: 10.3389/fpsyg.2019.00567

Hahn, D. (2020). The psychological well-being of student entrepreneurs: a social identity perspective. *Int. Entrep. Manag. J.* 16, 467–499. doi: 10.1007/s11365-019-00607-3

Hair, J. F., Black, W. C., Babin, B. J., and Anderson, R. E. (2018). *Multivariate data analysis. 8th* Edn. London, United Kingdom: Pearson.

Hodzic, S., Botella, P. R., and Costa, H. (2016). Are emotionally intelligent students more resilient to stress? *Behav. Psychol.* 24, 253–272. Available at: https://www.behavioralpsycho.com/wp-content/uploads/2018/10/04.Hodzic_24-2oa-1.pdf

Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct. Equ. Model.* 6, 1–55. doi: 10.1080/10705519909540118

Jazaieri, H., Goldin, P. R., Werner, K., Ziv, M., and Gross, J. J. (2012). A randomized trial of MBSR versus aerobic exercise for social anxiety disorder. *J. Clin. Psychol.* 68, 715–731. doi: 10.1002/jclp.21863

Kashdan, T. B., and Breen, W. E. (2008). Social anxiety and positive emotions: a prospective examination of a self-regulatory model with tendencies to suppress or express emotions as a moderating variable. *Behav. Therapy* 39, 1–12. doi: 10.1016/j.beth.2007.02.003

Kashdan, T. B., and Steger, M. F. (2006). Expanding the topography of social anxiety an experience-sampling assessment of positive emotions, positive events, and emotion suppression. *Psychol. Sci.* 17, 120–128. doi: 10.1111/j.1467-9280.2006.01674.x

Kessler, R. C. (2003). The impairments caused by social phobia in the general population: implications for intervention. *Acta Psychiatr. Scand.* Supplement, 108(417), 19–27. doi: 10.1034/j.1600-0447.108.s417.2.x

Klemanski, D. H., Curtiss, J., McLaughlin, K. A., and Nolen-Hoeksema, S. (2017). Emotion regulation and the transdiagnostic role of repetitive negative thinking in adolescents with social anxiety and depression. *Cogn. Ther. Res.* 41, 206–219. doi: 10.1007/s10608-016-9817-6

Kline, R. B. (2016). *Principles and practice of structural equation modeling*. New York City, United States: The Guilford Press.

Kuo, T. M., Tsai, C. C., and Wang, J. C. (2021). Linking web-based learning self-efficacy and learning engagement in MOOCs: the role of online academic hardiness. *Internet High. Educ.* 51:100819. doi: 10.1016/j.iheduc.2021.100819

Kwon, S. J., Kim, Y., and Kwak, Y. (2018). Difficulties faced by university students with self-reported symptoms of attention-deficit hyperactivity disorder: a qualitative study. *Child Adolesc. Psychiatry Ment. Health* 12:12. doi: 10.1186/s13034-018-0218-3

Li, D. (2020). Influence of the youth's psychological capital on social anxiety during the COVID-19 pandemic outbreak: the mediating role of coping style. *Iran. J. Public Health* 49, 2060–2068. doi: 10.18502/ijph.v49i11.4721

Makadi, E., and Koszycki, D. (2020). Exploring connections between self-compassion, mindfulness, and social anxiety. *Mindfulness* 11, 480–492. doi: 10.1007/s12671-019-01270-z

Marsh, H. W., Hau, K. T., and Wen, Z. (2004). In search of golden rules: comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. *Struct. Equ. Model.* 11, 320–341. doi: 10.1207/s15328007sem1103_2

Martínez-Marín, M. D., and Martínez, C. (2019). Subjective well-being and gender-typed attributes in adolescents: the relevance of emotional intelligence. *Aust. J. Psychol.* 71, 296–304. doi: 10.1111/ajpy.12247

Masrek, M. N., Ahmed, W., Jalil, A., and Baharuddin, M. F. (2022). Mobile game addiction and social interaction anxiety of malaysian youth. *Environ. Behav. Proc. J.* 7, 3–8. doi: 10.21834/ebpj.v7isi10.4094

Masters, M. R., Zimmer-Gembeck, M. J., and Farrell, L. J. (2019). Transactional associations between adolescents' emotion dysregulation and symptoms of social anxiety and depression: a longitudinal study. *J. Early Adolesc.* 39, 1085–1109. doi: 10.1177/0272431618806053

Mattick, R. P., and Clarke, J. C. (1998). Development and validation of measures of social phobia scrutiny fear and social interaction anxiety. *Behav. Res. Ther.* 36, 455–470. doi: 10.1016/S0005-7967(97)10031-6

Medda, E., Toccaceli, V., Gigantesco, A., Picardi, A., Fagnani, C., and Stazi, M. A. (2022). The COVID-19 pandemic in Italy: depressive symptoms immediately before and after the first lockdown. *J. Affect. Disord.* 298, 202–208. doi: 10.1016/j.jad.2021.10.129

Nguyen, B. T. N., Nguyen, T. T., and Le, U. T. T. (2022). Nomophobia and stress among Vietnamese high school students in COVID-19 pandemic: a mediation model of loneliness. *J. Biochem. Technol.* 13, 34–40. doi: 10.51847/zn5yxlp0nk

O'Toole, M. S., Hougaard, E., and Mennin, D. S. (2013). Social anxiety and emotion knowledge: a meta-analysis. *J. Anxiety Disord.* 27, 98–108. doi: 10.1016/j.janxdis.2012.09.005

Obschonka, M., Gewirtz, A. H., and Zhu, L. (2021). Psychological implications of the COVID-19 pandemic around the world: introduction to the special issue. *Int. J. Psychol.* 56, 493–497. doi: 10.1002/ijop.12793

Özdin, S., and Bayrak Özdin, Ş. (2020). Levels and predictors of anxiety, depression and health anxiety during COVID-19 pandemic in Turkish society: the importance of gender. *Int. J. Soc. Psychiatry* 66, 504–511. doi: 10.1177/0020764020927051

Parhiala, P., Torppa, M., Vasalampi, K., Eklund, K., Poikkeus, A. M., and Aro, T. (2018). Profiles of school motivation and emotional well-being among adolescents: associations with math and reading performance. *Learn. Individ. Differ.* 61, 196–204. doi: 10.1016/j.lindif.2017.12.003

Petrides, K. V., Sanchez-Ruiz, M. J., Siegling, A. B., Saklofske, D. H., and Mavroveli, S. (2018). "Emotional intelligence as personality: measurement and role of trait emotional intelligence in educational contexts" in *Emotional intelligence in education*. eds. K. V. Keefer, J. D. A. Parker and D. H. Saklofske (New York City, United States: Springer), 49–81, New York City, United States.

Pietrabissa, G., and Simpson, S. G. (2020). Psychological consequences of social isolation during COVID-19 outbreak. *Front. Psychol.* 11:2201. doi: 10.3389/fpsyg.2020.02201

Racine, S., Miller, A., Mehak, A., and Trolio, V. (2022). Examining risk and protective factors for psychological health during the COVID-19 pandemic. *Anxiety Stress Coping* 35, 124–140. doi: 10.1080/10615806.2021.1958789

Ramos-Díaz, E., Rodríguez-Fernández, A., Axpe, I., and Ferrara, M. (2019). Perceived emotional intelligence and life satisfaction among adolescent students: the mediating role of resilience. *J. Happiness Stud.* 20, 2489–2506. doi: 10.1007/s10902-018-0058-0

Rodríguez-Hidalgo, A. J., Pantaleón, Y., Dios, I., and Falla, D. (2020). Fear of COVID-19, stress, and anxiety in university undergraduate students: a predictive model for depression. *Front. Psychol.* 11:591797. doi: 10.3389/fpsyg.2020.591797

Roth, D., Antony, M. M., and Swinson, R. P. (2001). Interpretations for anxiety symptoms in social phobia. *Behav. Res. Therapy* 39, 129–138. doi: 10.1016/S0005-7967(99)00159-X

Rozen, N., and Aderka, I. M. (2023). Emotions in social anxiety disorder: a review. *J. Anxiety Disord.* 95:102696. doi: 10.1016/j.janxdis.2023.102696

Salguero, J. M., Palomera, R., and Fernández-Berrocal, P. (2012). Perceived emotional intelligence as predictor of psychological adjustment in adolescents: a 1-year prospective study. *Eur. J. Psychol. Educ.* 27, 21–34. doi: 10.1007/s10212-011-0063-8

Salovey, P., Mayer, J. D., Goldman, S. L., Turvey, C., and Palfai, T. P. (1995). "Emotional attention, clarity, and repair: exploring emotional intelligence using the trait meta-modo scale" in *Emotion, disclosure, and health*. ed. J. W. Pennebaker (Washington DC, United States: American Psychological Association), 125–154.

Sánchez-Álvarez, N., Extremera, N., and Fernández-Berrocal, P. (2016). The relation between emotional intelligence and subjective well-being: a meta-analytic investigation. *J. Posit. Psychol.* 11, 276–285. doi: 10.1080/17439760.2015.1058968

Soper, D. S. (2023). A-priori Sample Size Calculator for Structural Equation Models [Software]. Available at: https://www.danielsoper.com/statcalc/ (Accessed June 15, 2023).

Sturgill, R., Martinasek, M., Schmidt, T., and Goyal, R. (2021). A novel artificial intelligence-powered emotional intelligence and mindfulness app (Ajivar) for the college student population during the COVID-19 pandemic: quantitative questionnaire study. *JMIR Form. Res.* 5:e25372. doi: 10.2196/25372

Tabachnick, B. G., and Fidell, L. S. (2019). *Using multivariate statistics*. *7th* Edn. London, United Kingdom: Pearson.

Thompson, R. J., Boden, M. T., and Gotlib, I. H. (2017). Emotional variability and clarity in depression and social anxiety. *Cognit. Emot.* 31, 98–108. doi: 10.1080/02699931.2015.1084908

Torales, J., O'Higgins, M., Castaldelli-Maia, J. M., and Ventriglio, A. (2020). The outbreak of COVID-19 coronavirus and its impact on global mental health. *Int. J. Soc. Psychiatry* 66, 317–320. doi: 10.1177/0020764020915212

Torres-Gázquez, S. D. C., López-García, G. D., and Granero-Gallegos, A. (2023). Emotional intelligence and resilience in secondary school physical education students during the COVID-19 pandemic. *Espiral* 16, 51–63. doi: 10.25115/ecp.v16i32.9098

Turk, C. L., Heimberg, R. G., Luterek, J. A., Mennin, D. S., and Fresco, D. M. (2005). Emotion dysregulation in generalized anxiety disorder: a comparison with social anxiety disorder. *Cogn. Ther. Res.* 29, 89–106. doi: 10.1007/s10608-005-1651-1

Valdivia, J. A., Rubio, J. C. A., and French, B. F. (2015). Examination of the Spanish trait meta-mood scale–24 factor structure in a Mexican setting. *J. Psychoeduc. Assess.* 33, 473–482. doi: 10.1177/0734282914552052

Valenti, G. D., Bottaro, R., and Faraci, P. (2022). Effects of difficulty in handling emotions and social interactions on nomophobia: Examining the mediating role of feelings of loneliness. *Int. J. Ment. Heal. Addict.*, 1–15. doi: 10.1007/s11469-022-00888-w

Von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., and Vandenbroucke, J. P. (2008). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bull. World Health Organ.* 85, 867–872. doi: 10.2471/BLT.07.045120

Weeden, K. A., and Cornwell, B. (2020). The small-world network of college classes: implications for epidemic spread on a university campus. *Sociol. Sci.* 7, 222–241. doi: 10.15195/V7.A9

Wells, A., and Papageorgiou, C. (2001). Social phobic interoception: effects of bodily information on anxiety, beliefs and self-processing. *Behav. Res. Ther.* 39, 1–11. doi: 10.1016/s0005-7967(99)00146-1

Werner, K. H., Goldin, P. R., Ball, T. M., Heimberg, R. G., and Gross, J. J. (2011). Assessing emotion regulation in social anxiety disorder: the emotion regulation interview. *J. Psychopathol. Behav. Assess.* 33, 346–354. doi: 10.1007/s10862-011-9225-x

Wittchen, H. U., Fuetsch, M., Sonntag, H., Müller, N., and Liebowitz, M. (2000). Disability and quality of life in pure and comorbid social phobia. Findings from a controlled study. *Eur. Psychiatry* 15, 46–58. doi: 10.1016/s0924-9338(00)00211-x

Xiong, J., Lipsitz, O., Nasri, F., Lui, L. M. W., Gill, H., Phan, L., et al. (2020). Impact of COVID-19 pandemic on mental health in the general population: a systematic review. *J. Affect. Disord.* 277, 55–64. doi: 10.1016/j.jad.2020.08.001

Zwilling, M. (2022). The impact of nomophobia, stress, and loneliness on smartphone addiction among young adults during and after the COVID-19 pandemic: an Israeli case analysis. *Sustainability* 14:3229. doi: 10.3390/su14063229

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Profile analysis through self-determination theory and intention to be physically active: differences according to gender and age

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Introduction: Physical Education in the current education system has various objectives, including educating students on the values of physical activity and increasing the physical activity levels of students.

Objective: The purpose of the present study is to analyze the motivational profiles of students, to understand which profiles have higher levels of responsibility, satisfaction of autonomy, competence, and social relationship needs; intention to be physically active; and perception of autonomy support.

Methods: A total of 752 students from Primary, Secondary, and Non-compulsory Education ($M = 13.809$; $SD = 1.984$, 47.9% boys and 52.1% girls), from different educational centers in Spain, participated in the study, to whom a series of questionnaires were administered to find out their values of the mentioned variables. The results established the existence of four profiles: "high quality," "low quality," "high quantity," and "low quantity" of motivation.

Results: The results reflect that the students of the "high quality" and "high quantity" profiles had higher values in all the variables in relation to the other two groups (except in amotivation and external regulation), discussing the differential analysis between the four groups. The group with the best results was the "high quantity" profile, as opposed to the "low quantity" profile. In turn, no differences were found according to gender, but according to the educational stage, the Primary Education stage was more related to the more self-determined profiles.

Discussion and conclusion: Therefore, it is necessary to look for more self-determined motivational profiles from an early age in order to improve levels of responsibility, perception of autonomy, satisfaction of basic psychological needs, and the intention to be physically active.

KEYWORDS

Physical Education, autonomy support, responsibility, physical activity intention, basic psychological needs, physical activity

1. Introduction

Physical activity plays a crucial role in the overall well-being and development of young people. Numerous studies have highlighted the positive impact of regular exercise on various aspects of adolescent health. According to Meng et al. (2022), physical activity in students can improve body composition, cardiorespiratory fitness, and cardiometabolic markers. Additionally, research conducted by Janssen and Leblanc (2010) highlighted the association between physical activity and enhanced mental health, including reduced symptoms of anxiety and depression. Moreover, findings from a meta-analysis by Eime et al. (2013) revealed that participation in sports and physical activities positively influences social interactions and fosters a sense of belonging in young people. These findings collectively emphasize the importance of promoting and encouraging physical activity among young people to ensure their holistic development and well-being.

In this sense, promoting physical activity through education is of paramount importance in fostering a healthier and more active society. As pointed out by Tremblay et al. (2014), incorporating physical activity into the educational curriculum not only improves students' overall health but also positively impacts their cognitive and academic performance. This synergy between education and physical activity is further supported by the findings of Day et al. (2019), who wrote that well-designed educational programs can effectively influence behavior change and create lasting habits that promote a physically active lifestyle.

On the other hand, motivation can be defined as the internal drive and enthusiasm that initiates, guides, and sustains goal-directed behavior. It is the force that compels individuals to act in pursuit of their desires and objectives, pushing them to overcome obstacles and persevere in the face of challenges. The Theory of Self-determination (SDT), proposed by Deci and Ryan (1985), is a crucial framework for understanding human motivation and its significance in various domains. According to Deci and Ryan (2000), the theory posits that individuals have innate psychological needs (BPN): autonomy, which reflects the possibility of carrying out activities by one's own choice (Reeve, 2006); competence, involving a desire to achieve satisfactory results (Deci and Ryan, 1985); and relatedness, which refers to having a good social relationship with others, i.e., a reciprocal relationship (Leyton-Roman et al., 2020), which is essential for fostering intrinsic motivation. This theory explains that motivation goes from more autonomous and self-determined states of motivation (intrinsic motivation), continuing through identified motivation and introjected regulation, until it reaches more external motivation (extrinsic motivation) and, finally, lack of motivation (amotivation). In this field, White et al. (2021) focused on analyzing SDT, explaining that this theory is organized along a continuum involving the level of self-determination of a subject (i.e., the degree to which behavior is performed voluntarily, especially in intrinsic and identified motivation). Furthermore, Vallerand et al. (1992) said that intrinsic motivation plays a pivotal role in driving individuals to engage in activities for the inherent enjoyment and satisfaction they bring, leading to better performance and overall well-being. In educational settings, teachers who support students' autonomy and provide opportunities for skill development and interpersonal connections can foster a sense of intrinsic motivation (Vansteenkiste et al., 2009), ultimately enhancing learning outcomes and promoting a positive learning environment.

Motivation has been widely studied by educational researchers. For instance, the authors of the SDT theory, Deci and Ryan (2017), investigated the significance of intrinsic motivation in students' learning experiences and revealed that when learners are intrinsically motivated, they exhibit a genuine interest in the subject matter, leading to enhanced comprehension and long-term retention. At the same time, Physical Education plays a crucial role in fostering motivation (Moy et al., 2016) among students. In brief, SDT is a social cognitive theory that helps to explain student motivation in the context of PE classes (Deci and Ryan, 2000; Leyton-Roman et al., 2020).

The results of promoting motivation and autonomy in Physical Education classes facilitate the enhanced responsibility of students (Pozo et al., 2018; Valero-Valenzuela et al., 2019), autonomy support perception (Chang et al., 2016; Gil-Arias et al., 2020), or physical activity intention (Leyton-Roman et al., 2020).

In this line BPNs are determined by the social environment and autonomy support. In this sense, autonomy support consists of giving students the opportunity to make their own decisions (Reeve, 2016) and this variable is one of the most studied factors in the academic context. In this field, the relationship between autonomy support and BPN has been widely studied by different authors (Aguirre et al., 2016; Pérez-González et al., 2019; Gil-Arias et al., 2020; McCurdy et al., 2020) and this autonomy support is known as a facilitator of students' autonomous behaviors (Borg and Alshumaimeri, 2019).

On the other hand, physical activity intention is a variable that predicts physical activity (Camacho-Miñano et al., 2013; Moreno-Murcia et al., 2018; Cid et al., 2019). Physical activity intention is important to reduce sedentary behaviors (Biswas et al., 2015; Edwardson et al., 2020) and improve physical activity during free time and self-determined motivation (Franco et al., 2017); it also has other benefits like improved memory, attention, information processing levels (Hillman et al., 2014), and self-esteem (Singh et al., 2015).

Responsibility is becoming an increasingly important phenomenon (Bugdayci, 2019) and is defined as making selections and accepting the consequences and effects of these selections, including taking care of oneself and others, fulfilling our obligations, and participating in society (Lickona, 1991). There are numerous recent studies based on the importance of increasing responsibility in students. For instance, the review by Shen et al. (2022) provides recommendations for responsibility programs, including collaborative efforts focusing on the importance of developing responsibility for students. This study includes 41 high-quality articles on the use of a Personal and Social Responsibility Model, whose main purpose is to promote responsibility in students, and many of these studies are linked to the SDT (Manzano-Sánchez and Valero-Valenzuela, 2019; Merino-Barrero et al., 2019).

However, there are a number of gender differences in motivation according to the meta-analysis of Turhan (2020). Usually, girls are more likely to be motivated by intrinsic factors, such as personal interests or helping others, and they have more academic motivation, while boys are more likely to be motivated by extrinsic factors, such as rewards and recognition, and their academic motivation is lower than girls (Bugler et al., 2015). In line with this, physical activity is lower in girls than in boys, but the most important gap in the literature is that motivation for physical activity support and the premise of self-determined motivation are strongly linked to higher physical activity participation (Lauderdale et al., 2015). This conclusion is in line with that of Shen (2015), who said that boys had higher intrinsic motivation and teacher autonomy support. The same conclusion was achieved by Abdoshahi et al. (2022) in a study involving primary school students, where the boys had higher scores in perceived autonomy support, intrinsic motivation, and intention to physically perform activities.

In the same field, it is important to study the age of participants because of the influence of educational stage on the academic motivation of girls and boys (Turhan, 2020); for this reason, studying both together is highly important. According to age, Nigg and Amarto (2015) indicate that the habits that are acquired during infancy and Primary school have a positive or negative impact on adolescence and in the future. Thus, the transition from primary to Secondary Education has been described as a phase of psychological, biological, and emotional transformation typical of entry into adolescence (Prieto and Delgado, 2017).

The secondary stage is considered a period of great difficulties due to the lack of motivation toward studies (Martínez and Blanco, 2005). In this sense, Manzano-Sánchez (2021) said that secondary school students have worse values in relation to motivation, BPNs, and responsibility than primary school students. Physical activity according to Singerland et al. (2011) is lower in secondary school students than primary students, especially in girls; furthermore, secondary school boys were found to be more active than girls. However, Jago et al. (2012) indicated that boys' after-school physical activity declined by 16% after the move from primary to secondary school, compared to a 12% decline for girls. This is not a conclusion regarding whether the reduction of physical activity is higher in boys or girls, but there is evidently a reduction when students progress to the Secondary Education stage.

The purpose of this study is to study the motivational profiles of secondary and primary students to identify the differences in physical activity intention, autonomy support, and responsibility, identifying the differences between gender and educational stage. We hypothesized that (1) there would be different motivational profiles following the theory of Deci and Ryan and different studies (Yli-Piipari et al., 2009; Haerens et al., 2010; Sánchez-Oliva et al., 2015), (2) primary students would be more likely to be in the "high quality" or "high quantity" profiles than secondary and non-compulsory school students (Manzano-Sánchez, 2021), and (3) boys would have higher intention to be physically active and higher intrinsic motivation than girls, especially in the secondary stage (Bugler et al., 2015; Turhan, 2020; Aznar-Ballesta and Vernetta, 2023).

2. Method

2.1. Procedure

This is a cross-sectional and quantitative study. The questionnaires were coded on the online survey platform Google Forms[1] and dates were collected from February to May 2023. First, contact was made with the different participating centers, through well-known Physical Education teachers, having different meetings with the corresponding management teams via Zoom or in person from different centers of Spain, specifically, Murcia (Región de Murcia), Alicante (Comunidad Valenciana), and Toledo (Castilla La Mancha). The link to the questionnaire was sent to Physical Education teachers, and a Zoom meeting was carried out to explain how to pass the survey to the students, this meeting lasted between 20 and 25 min. This questionnaire started with a presentation of the study, informing the participants of the objectives, including a clause of confidentiality of the data, where the participants had to indicate in the first place that they agreed to participate in the study and that they had understood the indicated information. After that, they answered sociodemographic questions and completed different questionnaires about motivation, physical activity intention, responsibility, and autonomy support. The time to complete the questionnaire was approximately 20–25 min. All procedures that were carried out were in accordance with the standards of the Helsinki Declaration and were approved by the University of Murcia Ethical Committee (1,685/2017).

2.2. Participants

This study adopted accessibility and convenience sampling selection. A total of 775 questionnaires were recovered, and after statistical atypical case selection with Mahalanobis Distance and according to exclusion criteria (one answer per participant and an answer to all questions), the final sample consisted of 752 students (97.03%, M = 13.675; SD = 1.967) from three Spanish regions: Comunidad Valenciana Region de Murcia and Castilla-La Mancha. The sample consisted of 360 boys (47.9%) and 392 girls (52.1%). Following the Spanish Education System, the students were from Primary and Secondary Education. Specifically, 253 (33.6%) from Primary Education (year 4 to year 6); Secondary Education, from year 7 to year 10 (61.3%); and 38 from non-compulsory education (5.1%).

2.3. Measures

2.3.1. Academic motivation

A Motivation in Physical Education Questionnaire was used [CMEF, Sánchez-Oliva et al. (2012)]. This questionnaire is composed of 20 items. The items are established on a Likert scale from totally disagree (1) to totally agree (5). This questionnaire includes four items for each scale. This questionnaire is composed by five scales. Specifically, intrinsic motivation ("Because Physical Education is fun"), identified motivation ("because I value the benefits that this subject can have on my self-development"), introjected regulation ("because it's what I have to do to feel good"), external regulation ("because it is approved by the teacher and the classmates"), and amotivation ("I do not understand why we should have Physical Education"). The alpha's Cronbach values were $\alpha = 0.867$ (intrinsic motivation), $\alpha = 0.866$ (identified motivation), $\alpha = 0.700$ (introjected regulation), $\alpha = 0.781$ (external regulation), and $\alpha = 0.702$ (amotivation).

2.3.2. Satisfaction of basic psychological needs

Basic Psychological Needs Satisfaction Questionnaire [BPNES by Vlachopoulos and Michailidou (2006)]: to measure the satisfaction of basic psychological needs (BPNs). A Spanish version from Moreno-Murcia et al. (2008) was used. This scale has 12 items that aim to investigate autonomy values ("the types of exercise I do are in line with my interests"), competence ("exercising is something I do very well"), and relationship ("I feel very comfortable with my colleagues"). This questionnaire has a Likert-type scale from 1 (totally disagree) to 5 (totally agree). The Cronbach's alpha values obtained were $\alpha = 0.842$ (autonomy), $\alpha = 0.818$ (competence), and $\alpha = 0.866$ (relationship).

2.3.3. Responsibility

A Personal and Social Responsibility Scale [PSRQ by Li et al. (2008)] was used with the Spanish version developed by Escartí et al.

1 https://forms.gle/gbZMXMRBnrwnztUg7

(2011). This questionnaire is composed of two scales (personal responsibility and social responsibility) with a total of fourteen items and a Likert-type scale ranging from totally agree (1) to totally disagree (6). The internal consistency was $\alpha = 0.841$ for personal responsibility and $\alpha = 0.904$ in the case of social responsibility.

2.3.4. Autonomy support

An Autonomy Support Scale (EAA-EF, Moreno-Murcia et al., 2020) was used to check the perception of teacher support by students. This questionnaire has 11 items and a Likert scale with five responses, ranging from definitely not (1) to definitely yes (5). An example of an item is "They value our ideas and suggestions and let us propose things." The internal consistency value was $\alpha = 0.828$.

2.3.5. Physical activity intention

Measurement of the Intention to be Physically Active [MIFA in Spanish by Moreno-Murcia et al. (2008) adapted from Hein et al., (2004)] was used to analyze the physical activity intention of the participants. This scale is composed of five items on a Likert scale from 1 "strongly disagree" to 5 "strongly agree." An example of an item is "I usually practice sports in my free time." The internal consistency value was $\alpha = 0.811$.

2.4. Statistical analysis

First, the database was filtered by applying the Mahalanobis distance once the data from the questionnaires had been entered, this distance was applied considering the variables that were built for the clusters (intrinsic motivation, identified motivation, introjected regulation, external regulation, and amotivation). Next, we calculated the mean and standard deviation for the scores and the data were Z-transformed to be standardized. We also investigated the correlation between variables, and the values of skewness and kurtosis were used to check the normality, considering values <3 and < 7, respectively, as normal values (Curran et al., 1996) and < 1.98 following Field (2017). After that, the Cronbach's alpha coefficient was calculated to check the reliability of each variable. All variables that had values over 0.70 were considered acceptable (Viladrich et al., 2017).

Then, we checked the student's profiles in a two-step cluster analysis approach using a combination of hierarchical and non-hierarchical methods (Hair et al., 2018). Subsequently, a hierarchical conglomerate analysis was performed using Ward's method (Euclidean distance square) with Z-standardized scores of intrinsic motivation, identified motivation, introjected regulation, external regulation, and amotivation. We checked the dendrogram with a distance between 5 and 10 points, and a four-cluster solution was found to be the most suitable, so we selected this solution.

Furthermore, a univariate analysis of variance was performed to check the explanatory power of the cluster solution. In addition, we carried out a double-split cross-validation approach (the sample was randomly split into halves, and the same procedure was then repeated). The degree of agreement with cluster solution was 0.61 ($p = 0.001$) with the Cohen's kappa test. This is a value that is considered appropriate according to Breckenridge (2000).

In order to check the differences in the variables of BPNs, responsibility, physical activity intention, and autonomy support, a multivariate analysis of variance was performed, including F value and size effect. A *post hoc* contrast was used with the Bonferroni test to check the differences between profiles. Size effect was considered, following Richardson (2011), as small (< 0.01), medium (0.01 to 0.06), medium-large (0.06 to 0.14), or large (>0.14). Furthermore, we examined the differences in gender and educational stage within each subgroup by checking the differences in the distribution in the different profiles and the statistical differences. All analysis was performed with IBM SPSS, v. 25.0 (SSPS Inc. Chicago IL, EE.UU) establishing the level of significance $p < 0.05$.

3. Results

3.1. Descriptive and correlation results

Table 1 shows the descriptive results of the different variables under study. The correlation between the variables was positive in all cases and significant ($p < 0.01$), except for amotivation, which was negative (except for the autonomy and autonomy support variables, where it was not significant). It is noteworthy that the highest correlation happened between intrinsic motivation and the three BPNs. At the same time, the BPN of competence had the highest correlations with responsibility and intention to be physically active than autonomy and relation. In turn, the skewness and kurtosis values were checked, showing adequate values (<2) in any case, as indicated in the statistical analysis section.

3.2. Cluster profile result

With the final 752 participants (after exclusion criteria were applied), we started with cluster analysis. The dendrogram and the agglomeration coefficients reflected that the most adequate solution would be four or six profiles. Finally, we selected the four solutions due to the coefficients being increased highly by the movement between these two profiles, and the four-cluster solution has been supported in previous research (Sánchez-Oliva et al., 2015; Manzano-Sánchez et al., 2021). Finally, we checked the four-cluster solution and found that it was the profile that explained the variance of clustering of 68.2% ($R_2 = 0.682$; $R = 0.832$). This cluster had significant correlations in $p < 0.001$ for intrinsic motivation, identified motivation, introjected regulation, external regulation, and amotivation. In Figure 1, we can see the values of the four profiles.

The non-hierarchical cluster confirmed the four-cluster solution. The profiles were named "high quantity" (n = 301, 40.0%), with high values in all autonomous and external motivation; "low quality," with high values in amotivation and low values in more internal motivation ($n = 131$; 17.4%); "high quality," with low levels of external motivation and amotiation and positive values in identified and intrinsic motivation ($n = 239$; 31.8); and "low quality," with very low values of motivation (internal and external) and high levels of amotivation ($n = 81$; 10.8%). On the other hand, in Figure 2, we can see a scatter plot where the Y-axis is autonomous motivation and the X-axis is controlled and amotivation. We can see that the majority of the participants have values on the X-axis from 0.000 to 3.000 in the "low quality" and "low quantity" profiles. On the other hand, the majority of the other two profiles are between −1.000 and 2.000 on the Y-axis (Figure 2).

TABLE 1 Descriptive analysis and correlations.

		Mean	*SD*	*R*	*S*	*K*	2	3	4	5	6	7	8	9	10	11	12
1	Intrinsic M.	3.90	1.00	1–7	−0.900	0.174	0.780**	0.516**	0.358**	−0.216**	0.626**	0.680**	0.625**	0.540**	0.343**	0.383**	0.553**
2	Identified M.	3.65	1.04	1–5	−0.575	−0.432	1	0.534**	0.365**	−0.177**	0.643**	0.618**	0.560**	0.567**	0.343**	0.394**	0.497**
3	Introjected R.	3.05	1.02	1–5	−0.036	−0.661		1	0.585**	0.080*	0.485**	0.445**	0.364**	0.359**	0.227**	0.257**	0.343**
4	External R.	2.87	1.10	1–5	0.141	−0.869			1	0.215**	0.371**	0.320**	0.237**	0.311**	0.180**	0.176**	0.200**
5	Amotivation	1.63	0.82	1–5	1.312	0.966				1	−0.048	−0.138**	−0.154**	−0.059	−0.160**	−0.253**	−0.145**
6	Autonomy	3.12	1.03	1–5	−0.824	−0.057					1	0.660**	0.594**	0.639**	0.355**	0.348**	0.439**
7	Competence	3.70	0.95	1–5	−0.121	−0.701						1	0.693**	0.504**	0.408**	0.451**	0.615**
8	Relation	3.84	1.03	1–5	−0.584	−0.325							1	0.480**	0.444**	0.371**	0.490**
9	Autonomy S.	3.66	0.95	1–5	−0.797	−0.168								1	0.362**	0.323**	0.366**
10	RPS	4.96	0.98	1–6	−0.667	−0.145									1	0.707**	0.357**
11	RPP	5.02	0.96	1–6	−1.295	1.646										1	0.422**
12	MIFA	4.00	0.90	1–6	−1.318	1.511											1

M, Mean; SD, Standard deviation; R, Range; S, Skewness; K, Kurtosis; M, motivation; R, Regulation; S., Support; RPS, Social responsibility; RPP, Personal responsibility; MIFA, Physical activity intention = $p < 0.01$; * = $P < 0.05$.

In Table 2, we can check the differences between the motivation variables from each cluster. The multivariate effect was significant at $p < 0.001$, pointing to the violation of the assumption of homogeneity. In this sense, the "high quantity" profile has greater values of all kinds of motivation. On the other hand, the "low quality" profile was the profile with more amotivation values and reduced values in internal and external motivation. The "high quality" profile had lower values in amotivation and high levels in intrinsic and identified motivation, with intermediate values in extrinsic regulation and introjected motivation. Finally, the "low quantity" profile had lower values in all variables except amotivation, for which it had the second highest values.

Finally, according to one of the main purposes of this study, we investigated the values of responsibility, BPNs, autonomy support, and physical activity intention between the profiles (Table 3). In order to know which groups were different from each other, we used the Bonferroni-correction test.

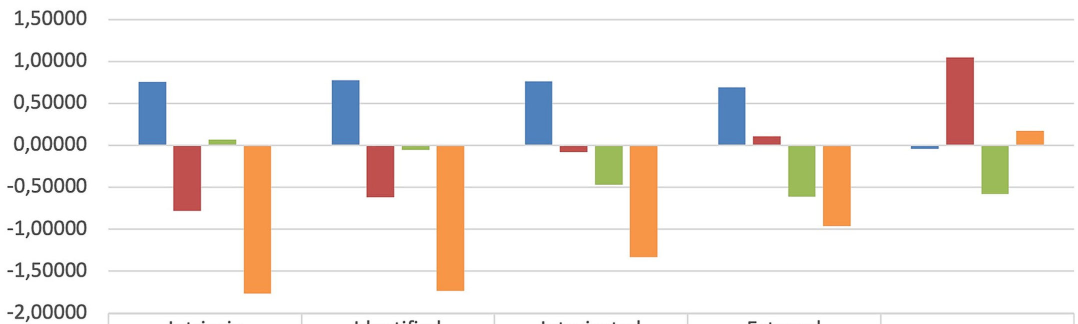
3.3. Differences in motivational profile between groups

The four motivational profiles identified significantly differed from one another with respect to BPNs, personal and social responsibility, autonomy support, and physical activity intention. The results, using multiple comparisons, contrasted with Bonferroni's correction, are in Table 4. *Post hoc* analysis reported that, in the case of autonomy, all variables had significant differences between clusters in $p < 0.01$ or $p < 0.001$ in favor of the "high quality" and "high quantity" profiles. Competence and relatedness followed a similar line, with higher values in the "high quality" and "high quantity" profiles. On the other hand, in personal and social responsibility, significant differences were found between the four motivational profiles, except between the "low quality" (2) and "low quantity" (4) profiles, with the highest values being recorded for the "high quality" profile, followed by the "high quantity" profile. Autonomy support had differences between profiles, with higher values in the "high quality" profile, followed by the "high quantity," "low quality," and finally, "low quantity" profiles.

Finally, physical activity intention was higher in the "high quality" profile and the "high quantity" profile, with lower values being recorded for the "low quality" profile, and lower still for the "low quantity" profile. The only variable that did not have differences between the groups was social responsibility (between high and low quality and low quantity) and the significance of personal responsibility and MIFA for these groups was low (near to 0.50).

3.4. Differences between profiles according to gender and educational stage

Following Manzano-Sánchez et al. (2021), to check the differences in the distribution of the motivational profiles found in terms of gender and the course, it was decided that a difference analysis using Pearson's chi-square statistic with cross tables would be performed. This test is adequate for observed and expected frequencies in a category to test whether all categories contain the same or different proportions of values for a user-specified proportion. We used corrected typified



	Intrinsic motivation	Identified motivation	Introjected regulation	External regulation	Amotivation
High Quantity	0,75919	0,77808	0,76345	0,69479	-0,04146
Low Quantity	-0,78060	-0,61913	-0,07887	0,11077	1,05082
High Quality	0,06929	-0,05293	-0,46756	-0,60915	-0,58139
Low Quality	-1,76320	-1,73389	-1,32989	-0,96366	0,17007

FIGURE 1
Motivational profiles.

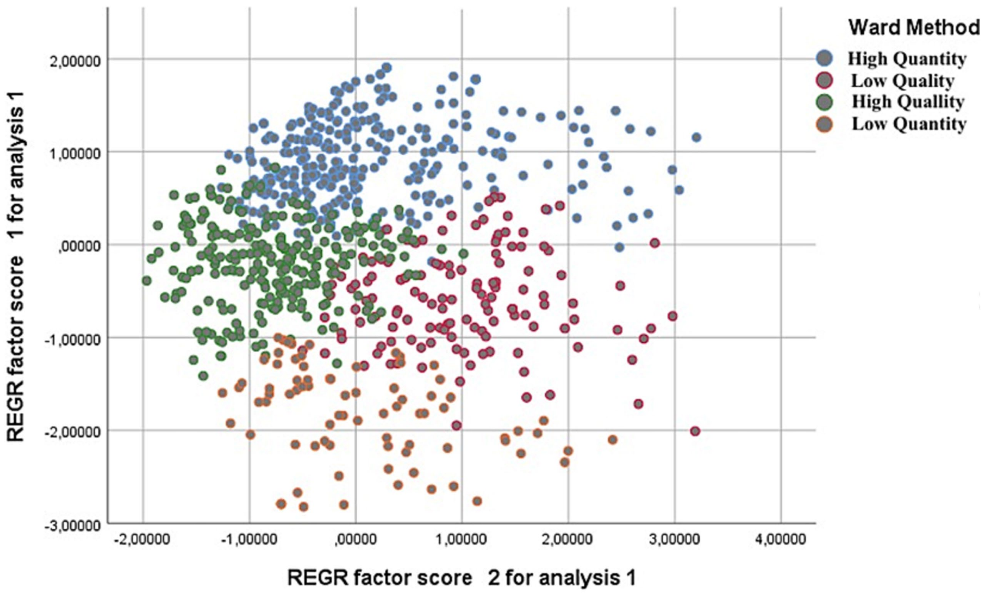


FIGURE 2
Dispersion diagram from cluster. Y-axis, Autonomous motivation; X-axis, Controlled motivation and amotivation.

residuals to provide us with information regarding where the differences were found (greater >1.90 indicated that differences were significant).

In this sense, we did not find any differences between genders in the group distribution; however, the educational stage was found to be related to the different profiles. In summary, primary school students were in the "high quantity" profile, and this group was the most adequate in motivation, responsibility, satisfaction of BPNs, autonomy support, and physical activity intention. On the other hand, Secondary students were the group with the second highest number of students in the "high quantity profile" and the group with the most students in the "high quality" profile (All these variables were greater than 1.9). Finally, Non-compulsory Education students had a similar distribution in their profiles, and the only difference was in the low quantity profile, with a standardized residual of 2.1 (21.1% of the participants) (Table 5).

3.5. Differences according to gender and educational stage

Finally, we investigated the differences according to gender and educational stage. Gender did not have any differences in any variables, with similar values between boys and girls, taking into account the sample in general (Table 6).

TABLE 2 Profile analysis according to motivation.

	Hiqh quantity		Low quality		High quality		Low quantity		*F*	*p*	eTa
	M	SD	*M*	SD	*M*	SD	*M*	SD			
Intrinsic motivation	4.66	0.40	3.11	0.71	3.97	0.61	2.13	0.73	515.813	0.000***	0.674
Identified motivation	4.46	0.47	3.01	0.73	3.60	0.76	1.85	0.54	433.140	0.000***	0.635
Introjected regulation	3.83	0.74	2.97	0.65	2.57	0.69	1.69	0.56	244.141	0.000***	0.495
External regulation	3.64	0.93	2.99	0.75	2.2	0.86	1.81	0.57	176,056	0.000***	0.414
Amotivation	1.60	0.87	2.50	0.67	1.16	0.29	1.77	0.80	108.809	0.000***	0.304

M de box = 551.441, f = 12.061, $p = < 0.001$; Pillai trace = 1.210 f (100.855), $p < 0.01$.
M, Mean; SD, Standard deviation; eTa, size effect; F, f-test from Multivariate analysis (MANOVA); *** $p < 0.001$.

TABLE 3 Profile analysis according to BPNs, responsibility, autonomy support, and physical activity intention.

	High quantity		Low quality		High quality		Low quantity		F	*p*	eTa
	M	SD	M	SD	M	SD	M	SD			
Autonomy	3.75	0.79	2.65	0.87	2.99	0.89	1.91	0.75	130.940	0.000**	0.344
Competence	4.28	0.60	3.13	0.84	3.71	0.80	2.47	0.86	160.497	0.000**	0.392
Relatedness	4.38	0.69	3.22	1.01	3.87	0.90	2.71	1.00	110.563	0.000**	0.207
RPP	5.29	0.73	4.51	1.08	5.01	0.88	4.31	1.32	37.101	0.000**	0.130
RPSS	5.34	0.65	4.59	1.09	5.14	0.83	4.20	1.26	48.435	0.000**	0.163
Autonomy_Support	4.15	0.66	3.28	0.90	3.58	0.86	2.72	1.15	78.985	0.000**	0.241
MIFA	4.44	0.61	3.43	0.85	4.05	0.76	3.13	1.14	90.650	0.000**	0.267

M de box = 420.376, f = 4.595, $p = < 0.001$.
Pillai trace = 0.258 *f* (22.719), $p = < 0.001$.
M, Mean; SD, Standard deviation; RPP, Personal responsibility; RPSS, Social responsibility; MIFA, Physical activity intention; eTa, size effect; F, *f*-value from Multivariate analysis (MANOVA); **$p < 0.001$.

TABLE 4 Analysis between clusters.

	1 vs. 2	1 vs. 3	1 vs. 4	2 vs. 3	2 vs. 4	3 vs. 4
Autonomy	1.97***	0.765***	1.844***	−0.331**	0.747***	1.079***
Competence	1.153***	0.565***	1.807***	−0.587***	0.654***	1.241***
Relatedness	1.160***	0.511***	1.677***	−0.649***	0.516***	1.165***
RPP	0.747***	0.202*	1.14***	−0.545***	0.389*	0.934***
RPSS	0.781***	0.284**	0.981***	−0.497***	0.200	0.697***
Autonomy_Support	0.868***	0.577***	1.431***	−0.292**	0.563***	0.855***
MIFA	1.006***	0.387***	1.308***	−0.619***	0.301*	0.920***

M, Mean; SD, Standard deviation; RPP, Personal responsibility; RPSS, Social responsibility; MIFA, Physical activity intention; eTa, size effect; F, *f*-test from Multivariate analysis (MANOVA); * $p < 0.05$; ** $p < 0.001$; *** $p < 0.001$; 1, "High quantity"; 2, "Low quality"; 3, "High quality"; 4, "Low quantity".

TABLE 5 Differences according to gender and educational stage.

	High quantity			Low quality			High quality			Low quantity			X^2	gl	*p*
	n	%	R	*n*	%	R	*n*	%	R	*n*	%	R			
Men	144	19.1%	0.0	64	8.5%	0.2	113	15.0%	0.2	9	1.2%	0.1	0.87	3	0.993
Girl	157	20.9%	0.0	67	8.9%	0.2	126	16.8%	0.2	64	8.5%	0.1			
P. School	146	57.7%	7.0	26	10.7%	3.5	71	28.1%	−1.6	9	3.6%	−4.5	64.544	6	0.000**
S. School	144	31.2%	6.2	94	20.4%	2.7	159	34.5%	2.0	64	13.9%	3.5			
NC School	11	28.9%	1.4	20	23.3%	1.5	9	23.7%	−1.1	8	21.1%	2.1			

P, Primary; S, Secondary; NC, Non-compulsory; R, Standardized Residual, SD, Standard Deviation; PBN, Basic Psychological Needs; X2, chi squared; gl, free grades.

TABLE 6 Gender and stage differences.

	Boys		Girls		F	*p*	eTa	Primary Education		Secondary Education		Non-compulsory Education		F	*p*	eTa
	M	SD	*M*	SD				*M*	SD	*M*	SD	*M*	SD			
Intrinsic motivation	3.88	0.98	3.91	1.02	0.264	0.609	0.000	4.31	0.81	3.70	1.02	3.49	1.13	36.270	0.000**	0.088
Identified motivation	3.61	1.02	3.69	1.06	1.443	0.248	0.002	4.07	0.86	3.47	1.05	3.10	1.07	36.775	0.000**	0.089
Introjected regulation	3.10	1.00	3.00	1.04	1.953	0.172	0.002	3.38	0.97	2.89	1.01	2.78	1.03	21.019	0.000**	0.053
External regulation	2.90	1.05	2.85	1.14	0.569	0.492	0.001	3.14	1.14	2.74	1.06	2.71	1.01	11.666	0.000**	0.030
Amotivation	1.65	0.85	1.62	0.80	0.282	0.519	0.001	1.63	0.84	1.63	0.81	1.70	0.81	0.120	0.888	0.000
MIFA	4.02	0.87	3.98	0.93	0.349	0.512	0.000	4.21	0.77	3.90	0.93	3.77	1.08	10.733	0.000**	0.035
Autonomy	3.08	1.01	3.15	1.04	0.920	0.372	0.001	3.44	0.93	2.96	1.04	2.90	0.93	19.431	0.000**	0.049
Competence	3.74	0.93	3.67	0.97	0.797	0.920	0.001	4.00	0.87	3.58	0.95	3.26	1.05	21.901	0.000**	0.055
Relatedness	3.84	1.02	3.84	1.03	0.002	0.962	0.000	4.22	0.84	3.67	1.05	3.42	1.14	28.834	0.000**	0.071
Autonomy_ Support	3.61	0.96	3.71	0.95	2.009	0.138	0.003	3.90	0.75	3.56	1.02	3.32	1.05	13.414	0.000**	0.035
Social_ Responsibility	4.91	1.01	5.01	0.96	1.912	0.167	0.003	5.26	0.84	4.79	1.00	4.98	1.20	18.884	0.000**	0.048
Personal_ Responsibility	4.98	0.97	5.06	0.95	1.173	0.279	0.002	5.33	0.70	4.87	1.03	4.85	1.06	20.751	0.000**	0.053

M de box = 66.766, f = 0.867, p = 0.793.793.
Pillai trace = 0.022, *f* (1.388), *p* = 0.166.
M, Mean; SD, Standard deviation; MIFA, Physical activity intention eTa, size effect; F, *f*-test from Multivariate analysis (MANOVA), *** $p < 0.001$.

However, Table 6 shows the differences between stages, especially in variables with $p < 0.001$, except in amotivation, where differences did not occur between groups. Primary Education is a stage where the students have higher levels of internal and external motivation to engage in physical activity, and at the same time, they have good satisfaction with their BPNs (all these variables are higher in this group compared to Secondary Education and Non-compulsory Education). On the other hand, they feel that their teacher provides them with a good environment to be autonomous and they feel high levels of social and personal responsibility.

The differences between Secondary Education and Non-compulsory Education are in intrinsic motivation and identified motivation, physical activity intention, relatedness and competence, and autonomy support (higher in Secondary Education) following the post-hoc test. However, Non-compulsory students had higher levels of social responsibility.

4. Discussion

The purpose of this study is to study the motivational profiles of secondary and primary school students to identify the differences in physical activity intention, autonomy support, and responsibility and show the differences between gender and educational stage. The hypothesis was that (1) there would be four motivational profiles; (2) primary students would be more likely to be in the "high quality" or "high quantity" profiles than Secondary and Non-compulsory school students; and (3) boys would have higher intention to be active and have greater intrinsic motivation than girls, especially in the secondary stage.

According to the first hypothesis, we can confirm that there were four profiles, as initially hypothesized, agreeing with the studies by Sánchez-Oliva et al. (2015), where they found four profiles with 1,690 Secondary Education students, and Manzano-Sánchez et al. (2021), with 768 participants. However, in the studies cited, the levels of amotivation were also high in the profile called "high quantity," which possibly caused this profile to have fewer adaptive consequences than the "high quality" profile, indicating to the authors that it could be due to a "standardized response" from the participants, which was not the case in the present study. In our study, on the other hand, the "high quantity" profile proved to be the one with the most positive results. This indicates that high levels of internal and external motivation (not amotivation) could play a significant role in improving adherence to physical activity, improving responsibility, satisfying BPNs, and the perception of autonomy support. Finally, note that the solution of profiles is an area still under study since other studies have identified the existence of two profiles (Yli-Piipari et al., 2009) or even five profiles (Haerens et al., 2010), probably due to the use of different motivational variables like autonomous or controlled motivation or the self-determination index. In this sense, future studies have to consider the amotivation variable, since it could have a negative influence on a "high quantity" profile.

Secondly, based on the second hypothesis, we must highlight that Romera et al. (2022) evidenced the role of age and gender in different adolescent behaviors and that, usually, girls would have higher levels of social values and less disruptive behaviors. Following this author, preadolescence (primary school) would be a particularly relevant stage to educate and develop values and social rules adjusted to the context. Our study corroborates that the educational stage of students has a special relevance to motivational factors. In this way, the Primary Education stage had the highest percentage of students in the "high quantity" and "high quality" profiles, which translated into higher levels of intention to be physically active, satisfaction of BPNs, responsibility, and autonomy support. All of this generates the need for Physical Education to seek to improve motivation and adherence to physical activity outside and inside school (Hagger and Chatzisarantis, 2014; Sánchez-Oliva et al., 2015), allowing for this motivation to also improve educational values, such as social responsibility (Bagøien et al., 2010), as well as BPNs (Vasconcellos et al., 2020). Therefore, we can conclude that promoting motivation in Physical Education classes must begin from the earliest age to maintain these values in adolescence and at the end of the Secondary Education stage, when the values of physical activity and satisfaction of BPNs are low. The same is indicated by Abdoshahi et al. (2022), where Primary Education students have the highest levels of intrinsic motivation, autonomy support perception, and intention to be physically active.

Finally, regarding the third hypothesis, we did not find clear results, since we did not find statistically significant differences between boys and girls, neither in the distribution of the profiles, considering the standardized residuals, nor in the general values without taking the profiles into account. This contrasts with studies such as Aznar-Ballesta and Vernetta (2023), where girls were shown to have higher sports dropout rates than boys. Similarly, the review by Turhan (2020) indicates that girls tend to have higher values of intrinsic motivation and boys experience motivation more related to external rewards (Bugler et al., 2015). In turn, regarding the level of physical activity, Bugler et al. (2015) indicated that girls tend to perform less physical activity than boys, but in our case, this data is not indicated as it is similar in both genders. Likewise, Shen (2015) shows that motivation is usually higher in boys, and they have a greater perception of autonomy from their teachers, a result similar to that of Abdoshahi et al. (2022). On the other hand, we corroborate the results of Lauderdale et al. (2015), where it is indicated that when there is greater motivation (especially intrinsic), the levels of physical activity are higher. This may explain the non-existence of differences between genders in the intention to be physically active, since no differences were seen at the motivational level, showing the importance of generating an adequate climate of motivation to achieve these results. Therefore, we conclude in this sense that it is still necessary to continue investigating the role of gender in motivation and experiences related to SDT and the variables of responsibility, autonomy support, and the intention to be physically active. We also consider the necessity of following Turhan's suggestions, which insist on the importance of studying the motivation of girls and boys, especially in the change of educational stage from Primary to Secondary Education, since the habits that are generated in the early stages are necessary to create suitable habits in the future. It is worth highlighting the study of Cerro-Herrero et al. (2022) and the necessity to implement interventions that promote the vision of active movement to take advantage of the high levels of intention to be physically active. The study conducted by Ahmadi et al. (2023) is also interesting as they identified 57 motivational behaviors of teachers that could explain most of the motivational behaviors of students.

5. Limitations and future research

The main limitations of the study indicate the cross-sectional nature of the study, which does not allow for cause-effect relationships. Another limitation is the sample obtained in Non-compulsory Education students, which was reduced in relation to the rest of the participants. In turn, the solution of four motivational profiles has been widely studied, but it could have been considered to carry out profile analysis including BPNs or another variable, which could have varied the solutions. Finally, the use of larger samples from other countries or samples consisting of students with different socio-economic characteristics could be interesting to investigate the results in different social and cultural centers.

As a future line of study, it is recommended to carry out intervention studies where motivation is promoted within Physical Education classes to improve the satisfaction of basic psychological needs, especially seeking to use a teaching style where autonomy is encouraged to also improve adherence to physical activity. On the other hand, carrying out longitudinal studies or including larger samples, including different contexts, would be of great interest to the scientific community. Finally, it would be interesting to expand the sample to university students in order to understand whether the reduction of the variables studied continues at this stage, with the inclusion of new variables like satisfaction due to the mediating effect following SDT and physical activity intention (Pérez-Quero et al., 2023).

6. Conclusions and practical applications

It is concluded that there were four motivational profiles called "high quantity," "high quality," "low quantity," and "low quality," which were related to each other with the psychological needs of autonomy, competence and social relationships, responsibility, autonomy support, and the intention to be physically active. All profiles have statistically significant differences between all variables.

The profile that had more appropriate values was the so-called "high quantity" profile, which makes it necessary to promote motivation in Physical Education students (including external motivation), especially from an early age, to improve adherence to physical activity and the promotion of educational values. On the other hand, "high quality" was the second profile with more positive values of the variables under study, and "low quality" was the profile with the lowest values in intention to be physically active, responsibility, satisfaction of basic psychological needs, and perception of support for autonomy. No differences were found between girls and boys, but the students in Primary Education were in the most self-determined profiles.

For these reasons, motivation should be emphasized following the SDT from an early age to generate better habits related to physical activity and greater responsibility. Similarly, the interventions carried out in the field of education should focus on promoting physical activity and values such as responsibility with a teacher who conducts their classes promoting autonomy, competence, and relatedness, following recommendations for the use of behaviors based on the SDT, such as those made by Ahmadi et al. (2023).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by University of Murcia Ethical Committee (1685/2017). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Abdoshahi, M., Gholami, A., and Naeimikia, M. (2022). The correlation of autonomy support with intrinsic motivation, anxiety, and intention to do physical activities in children. *Int. J. Pediatr.* 10, 15623–15629. doi: 10.22038/IJP.2022.63021.4810

Aguirre, H. B., Tristán, J. L., López, J. M., Tomás, M. I., and Zamarripa, J. (2016). Coach interpersonal styles frustration of basic psychological needs and burnout: a longitudinal analysis. *Retos* 20, 132–137. doi: 10.47197/retos.v0i30.50097

Ahmadi, A., Noetel, M., Parker, P., Ryan, R. M., Ntoumanis, N., Reeve, J., et al. (2023). A classification system for teachers' motivational behaviors recommended in self-determination theory interventions. *J. Educ. Psychol.* doi: 10.1037/edu0000783, Advance online publciation

Aznar-Ballesta, A., and Vernetta, M. (2023). Influence of the satisfaction and importance of physical education on sports dropout in secondary school. *Espiral* 16, 18–28. doi: 10.25115/ecp.v16i32.8604

Bagøien, T. E., Halvari, H., and Nesheim, H. (2010). Self-determined motivation in physical education and its links to motivation for leisure-time physical activity, physical activity, and well-being in general. *Percept. Mot. Skills* 111, 407–432. doi: 10.2466/06.10.11.13.14.PMS.111.5.407-432

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., et al. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann. Intern. Med.* 162, 123–132. doi: 10.7326/M14-1651

Borg, S., and Alshumaimeri, Y. (2019). Language learner autonomy in a tertiary context: teachers' beliefs and practices. *Lang. Teach. Res.* 23, 9–38. doi: 10.1177/1362168817725759

Breckenridge, J. N. (2000). Validating cluster analysis: consistent replication and symmetry. *Multivar. Behav. Res.* 35, 285–261. doi: 10.1207/S15327906MBR3502_5

Bugdayci, S. (2019). Examining personal and social responsibility levels of secondary school students. *Univers. J. Educ. Res.* 7, 206–210. doi: 10.13189/ujer.2019.070126

Bugler, M., McGeown, S. P., and Clair-Thompson, H. (2015). Gender differences in adolescents' academic motivation and classroom behaviour. *Educ. Psychol.* 35, 541–556. doi: 10.1080/01443410.2013.389325

Camacho-Miñano, M. J., Fernández, E., Ramírez, E., and Blández, J. (2013). School physical education in promoting health-oriented physical activity in adolescence: a systematic review of programs. *Rev. Complut. De Educ.* 24, 9–26. doi: 10.5209/rev_RCED.2013.v24.n1.41189

Cerro-Herrero, D., Prieto-Prieto, J., Tapia-Serrano, M. A., Vaquero-Solís, M., and Sánchez-Miguel, P. A. (2022). Relationship between the intention to be physically active and active commuting to school: proposals for intervention to increase active commuting in children. *Espiral* 15, 51–58. doi: 10.25115/ecp.v15i30.5939

Chang, Y. K., Chen, S., Tu, K. W., and Chi, L. K. (2016). Effect of autonomy support on self-determined motivation in elementary physical education. *J. Sports Sci. Med.* 15, 460–466. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4974858/.

Cid, L., Pires, A., Borrego, C., Duarte-Mendes, P., Teixeira, D. S., Moutão, J. M., et al. (2019). Motivational determinants of physical education grades and the intention to practice sport in the future. *PLoS One* 14:e0217218. doi: 10.1371/journal.pone.0217218

Curran, P. J., West, S. G., and Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychol. Methods* 1:16. doi: 10.1037/1082-989X.1.1.16

Day, R. E., Sahota, P., and Christian, M. S. (2019). Effective implementation of primary school-based healthy lifestyle programmes: a qualitative study of views of school staff. *BMC Public Health* 19, 1–16. doi: 10.1186/s12889-019-7550-2

Deci, E. L., and Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. German: Springer Science and Business Media.

Deci, E. L., and Ryan, R. M. (2000). The" what" and" why" of goal pursuits: human needs and the self-determination of behavior. *Psychol. Inq.* 11, 227–268. doi: 10.1207/S15327965PLI1104_01

Deci, E. L., and Ryan, R. M. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. New York: Guilford Press.

Edwardson, C. L., Henson, J., Biddle, S. J., Davies, M. J., Khunti, K., Maylor, B., et al. (2020). activPAL and ActiGraph assessed sedentary behavior and cardiometabolic health markers. *Med. Sci. Sports Exerc.* 52, 391–397. doi: 10.1249/MSS.0000000000002138

Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J., and Payne, W. R. (2013). A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int. J. Behav. Nutr. Phys. Act.* 10:98. doi: 10.1186/1479-5868-10-98

Escartí, A., Gutiérrez, M., and Pascual, C. (2011). Psychometric properties of the Spanish version of the personal and social responsibility questionnaire in physical education contexts. *Rev. de Psicol. Del Dep.* 20, 119–130. Available at: https://www.redalyc.org/pdf/2351/235119302009.pdf

Field, A. (2017). *Discoring statistics using IBM SPSS statistics* (*5th*). New York: SAGE Publications.

Franco, E., Coterón, J., Gómez, V., and Laura, A. (2017). Relationship between motivation and intention to practice physical activity. A comparative study among spanish and argentinian adolescents. *Sport-TK* 6, 25–34. doi: 10.6018/280371

Gil-Arias, A., Claver, F., Práxedes, A., Villar, F. D., and Harvey, S. (2020). Autonomy support, motivational climate, enjoyment and perceived competence in physical education: impact of a hybrid teaching games for understanding/sport education unit. *Eur. Phys. Educ. Rev.* 26, 36–53. doi: 10.1177/1356336X18816997

Haerens, L., Kirk, D., Cardon, G., De Bourdeaudhuij, I., and Vansteenkiste, M. (2010). Motivational profiles for secondary school physical education and its relationship to the adoption of a physically active lifestyle among university students. *Eur. Phys. Educ. Rev.* 16, 117–139. doi: 10.1177/1356336X10381304

Hagger, M. S., and Chatzisarantis, N. L. D. (2014). An integrated behavior change model for physical activity. *Exerc. Sport Sci. Rev.* 42, 62–69. doi: 10.1249/JES.0000000000000008

Hair, J., Black, W., Babin, B., and Anderson, R. (2018) *Multi-variate data analysis*. Learning EMEA. San Francisco, CA

Hein, V., Müür, M., and Koka, A. (2004). Intention to be physically active after school graduation and its relationship to three types of intrinsic motivation. *Eur. Phys. Educ. Rev.* 10, 5–19. doi: 10.1177/1356336X04040618

Hillman, C. H., Pontifex, M. B., Castelli, D. M., Khan, N. A., Raine, L. B., Scudder, M. R., et al. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics* 134, e1063–e1071. doi: 10.1542/peds.2013-3219

Jago, R., Page, A. S., and Cooper, A. R. (2012). Friends and physical activity during the transition from primary to secondary school. *Med. Sci. Sports Exerc.* 44, 111–117. doi: 10.1249/MSS.0b013e318229df6e

Janssen, I., and Leblanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int. J. Behav. Nutr. Phys. Act.* 1, 1–16. doi: 10.1186/1479-5868-7-40

Lauderdale, M. E., Yli-Piipari, S., Irwin, C. C., and Layne, T. E. (2015). Gender differences regarding motivation for physical activity among college students: a self-determination approach. *Phys. Educ.* 72, 153–172. doi: 10.18666/TPE-2015-V72-I5-4682

Leyton-Roman, M., Nunez, J. L., and Jimenez-Castuera, R. (2020). The importance of supporting student autonomy in physical education classes to improve intention to be physically active. *Sustainability* 12:4251. doi: 10.3390/su12104251

Li, W., Wright, P., Rukavina, P., and Pickering, M. (2008). Measuring students' perceptions of personal and social responsibility and the relationship to intrinsic motivation in urban physical education. *J. Ohys. Educ. Recreat. Dance.* 27, 167–178. doi: 10.1123/jtpe.27.2.167

Lickona, T. (1991). *Educating for character: How our schools can respect and responsibility*. New York: Bantam Books.

Manzano-Sánchez, D. (2021). Differences between psychological aspects in primary education and secondary education. Motivation, basic psychological needs, responsibility, classroom climate, prosocial and antisocial behaviors and violence. *Espiral* 14, 9–18. doi: 10.25115/ecp.v14i28.4198

Manzano-Sánchez, D., Gómez-Marmol, A., Jiménez-Parra, J. F., Gil Bohórquez, I., and Valero-Valenzuela, A. (2021). Motivational profiles and their relationship with responsibility, school social climate and resilience in high school students. *PLoS One* 16:e0256293. doi: 10.1371/journal.pone.0256293

Manzano-Sánchez, D., and Valero-Valenzuela, A. (2019). Implementation of a model-based programme to promote personal and social responsibility and its effects on motivation, prosocial behaviours, violence and classroom climate in primary and secondary education. *Int. J. Public. Health. Res.* 16:4259. doi: 10.3390/ijerph16214259

Martínez, R. A., and Blanco, L. (2005). Failure and school dropout in Compulsory Secondary Education: involvement of the family and schools. *Aula. Abierta*. 85, 127–146.

McCurdy, A. L., Williams, K. N., Lee, G. Y., Benito-Gomez, M., and Fletcher, A. C. (2020). Measurement of parental autonomy support: a review of theoretical concerns and developmental considerations. *J. Fam. Theory Rev.* 12, 382–397. doi: 10.1111/jftr.12389

Meng, C., Yucheng, T., Shu, L., and Yu, Z. (2022). Effects of school-based high-intensity interval training on body composition, cardiorespiratory fitness and cardiometabolic markers in adolescent boys with obesity: a randomized controlled trial. *BMC Pediatr.* 22, 1–11. doi: 10.11186/s12887-021-03079-z

Merino-Barrero, J. A., Valero-Valenzuela, A., Pedreño, N. B., and Fernández-Río, J. (2019). Impact of a sustained TPSR program on students' responsibility, motivation, sportsmanship, and intention to be physically active. *J. Teach. Phys. Educ.* 39, 247–255. doi: 10.1123/jtpe.2019-0022

Moreno-Murcia, J. A., González-Cutre, D., Chillón, M., and Parra, N. Y. (2008). Adaptation of the basic psychological needs in exercise sccale to physical education. *Rev. Mex. Psicol.* 25, 295–303. Available at: https://www.redalyc.org/pdf/2430/243016308009.pdf

Moreno-Murcia, J. A., Huéscar, E., Andrés-Fabra, J. A., and Sánchez-Latorre, F. (2020). Adaptation and validation of autonomy support and controller style's scales in physical education: relationship with feed-back. *Rev. Int. Med. Cienc. Ac.* 21:3841. doi: 10.29035/rcaf.21.1.3

Moreno-Murcia, J., Huéscar-Hernández, E., and Ruiz, L. (2018). Perceptions of controlling teaching Behaviors and the effects on the motivation and behavior of high school physical education students. *Int. J. Public. Health. Res.* 15:2288. doi: 10.3390/ijerph15102288

Moy, B., Renshaw, I., and Davids, K. (2016). The impact of nonlinear pedagogy on physical education teacher education students' intrinsic motivation. *Phys. Educ. Sport Pedagogy.* 21, 517–538. doi: 10.1080/17408989.2015.1072506

Nigg, C., and Amarto, K. (2015). The influence of health behaviors during childhood on adolescent health behaviors, health indicators, and academic outcomes among participants from Hawaii. *Int. J. Behav. Med.* 22, 452–460. doi: 10.1007/s12529-014-9440-4

Pérez-González, A. M., Valero-Valenzuela, A., Moreno-Murcia, J. A., and Sánchez-Alcaraz, B. J. (2019). Systematic review of autonomy support in physical education. *Apunts* 138, 51–61. doi: 10.5672/apunts.2014-0983.es(2019/4).138.04

Pérez-Quero, F. J., Granero-Gallegos, A., Baena-Extremera, A., and Baños, R. (2023). Goal orientations of secondary school students and their intention to practise physical activity in their leisure time: mediation of physical education importance and satisfaction. *Healthcare* 11:568. doi: 10.3390/healthcare11040568

Pozo, P., Grao-Cruces, A., and Perez-Ordas, R. (2018). Teaching personal and social responsibility model-based programmes in physical education: a systematic review. *European Eur. Phys. Educ. REv.* 24, 56–75. doi: 10.1177/1356336X16664749

Prieto, J. L., and Delgado, F. J. H. (2017). Sports motivation in the transition from primary to secondary. *Ágora* 19, 88–101. doi: 10.24197/aefd.1.2017.88-101

Reeve, J. (2006). Teachers as facilitators: what autonomy-supportive teachers do and why their students benefit. *Elem. Sch. J.* 106, 225–236. doi: 10.1086/501484

Reeve, J. (2016). "Autonomy-supportive teaching: what it is, how to do it" in *Building autonomous learners*. eds. W. Liu, J. Wang and R. Ryan (London: Springer), 129–152.

Richardson, J. (2011). Eta squared and partial eta squared as measures of effect size in educational research. *Educ. Res. Rev.* 6, 135–147. doi: 10.1016/j.edurev.2010.12.001

Romera, E. M., Luque-González, R., García-Fernández, C. M., and Ortega-Ruiz, R. (2022). Social competence and bullying: the role of age and sex. *Educ. XXI.* 25, 309–333. doi: 10.5944/educXX1.30461

Sánchez-Oliva, D., Leo, F., Amado, D. M., González-Ponce, I., and García-Calvo, T. (2012). Develop of a questionnaire to assess the motivation in physical education. *Rev. Iberoam. Psicol. Ejerc.* 7, 227–250. Available at: https://www.redalyc.org/pdf/3111/311126611010.pdf

Sánchez-Oliva, D., Leo, F. M., Amado, D. A., Pulido-González, J. J., and García-Calvo, T. (2015). Analysis of motivational profiles and their relationship with adaptive behaviours in physical education classes. *Rev Latinoam. Psicol.* 47, 156–166. doi: 10.1016/j.rlp.2015.06.007

Shen, B. (2015). Gender differences in the relationship between teacher autonomy support and amotivation in physical education. *Sex Roles* 72, 163–172. doi: 10.1007/s11199-015-0448-2

Shen, Y., Martinek, T., and Dyson, B. P. (2022). Navigating the processes and products of the teaching personal and social responsibility model: a systematic literature review. *Quest* 74, 91–107. doi: 10.1080/00336297.2021.2017988

Singerland, M., Oomen, J., and Borghouts, L. (2011). Physical activity levels during Dutch primary and secondary school physical education. *Eur. J. Sport Sci.* 11, 249–257. doi: 10.1080/17461391.2010.506661

Singh, A., Uijtdewilligen, L., and Twisk, J. W. (2015). Physical activity and performance at school: a systematic review of the literature including a methodological quality assessment. *Arch. Pediatr. Adolesc. Med.* 169, 224–230. doi: 10.1001/archpediatrics.2011.716

Tremblay, M. S., Gray, C. E., Akinroye, K., Harrington, D. M., Katzmarzyk, P. T., Lambert, E. V., et al. (2014). Physical activity of children: a global matrix of grades comparing 15 countries. *J. Phys. Act. Health* 14, 573–578. doi: 10.1123/jpah.2017-0369

Turhan, N. S. (2020). Gender differences in academic motivation: a meta-analysis. *Int. J. Educ. Psychol.* 7, 211–224. doi: 10.17220/ijpes.2020.02.019

Valero-Valenzuela, A., Lopez, G., Moreno-Murcia, J. A., and Manzano-Sanchez, D. (2019). From students' personal and social responsibility to autonomy in physical education classes. *Sustainability* 11:6589. doi: 10.3390/su11236589

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière, N. M., Senécal, C., and Vallières, E. F. (1992). The academic motivation scale: a measure of intrinsic, extrinsic, and amotivation in education. *Educ. Psychol. Meas.* 52, 1003–1017. doi: 10.1177/0013164492052004025

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., and Lens, W. (2009). Motivational profiles from a self-determination perspective: the quality of motivation matters. *J. Educ. Psychol.* 101:671. doi: 10.1037/a0015083

Vasconcellos, D., Parker, P. D., Hilland, T., Cinelli, R., Owen, K. B., Kapsal, N., et al. (2020). Self-determination theory applied to physical education: A systematic review and meta-analysis. *J. Educ. Psychol.* 112, 1444–1469. doi: 10.1037/edu0000420

Viladrich, C., Angulo-Brunet, A., and Doval, E. (2017). A journey around alpha and omega to estimate internal consistency reliability. *An. De Psicol.* 33, 755–782. doi: 10.6018/analesps.33.3.268401

Vlachopoulos, S. P., and Michailidou, S. (2006). Development and initial validation of a measure of autonomy, competence, and relatedness in exercise: the basic psychological needs in exercise scale. *Meas. Phys. Educ. Exerc. Sci.* 10, 179–201. doi: 10.1207/s15327841mpee1003_4

White, R. L., Bennie, A., Vasconcellos, D., Cinelli, R., Hilland, T., Owen, K. B., et al. (2021). Self-determination theory in physical education: a systematic review of qualitative studies. *Teach. Teach. Educ.* 99:103247. doi: 10.1016/j.tate.2020.103247

Yli-Piipari, S., Watt, A., Jaakkola, T., Liukkonen, J., and Nurmi, J. (2009). Relationships between physical education students' motivational profiles, enjoyment, state anxiety, and self-reported physical activity. *J. Sports Sci. Med.* 8, 327–336.

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Exercise makes better mind: a data mining study on effect of physical activity on academic achievement of college students

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The effect of physical activity (PA) on academic achievement has long been a hot research issue in physical education, but few studies have been conducted using machine learning methods for analyzing activity behavior. In this paper, we collected the data on both physical activity and academic performance from 2,219 undergraduate students (Mean = 19 years) over a continuous period of 12 weeks within one academic semester. Based on students' behavioral indicators transformed from a running APP interface and the average academic course scores, two models were constructed and processed by CHAID decision tree for regression analysis and significance detection. It was found that first, to attain higher academic performance, it is imperative for students to not only exhibit exceptional activity regularity, but also sustain a reduced average step frequency; second, the students completing running exercise with an average frequency of 1 time/week and the duration of 16–25 min excelled over approximately 88 percentage of other students on academic performance; third, the processing validity and reliability of physical observation data in complex systems can be improved by utilizing decision tree as a leveraging machine learning tool and statistical method. These findings provide insights for educational practitioners and policymakers who will seek to enhance college students' academic performance through physical education programs, combined with data mining methods.

KEYWORDS

complex systems, college students, physical activity, running, academic performance, decision tree

Introduction

The relationship between physical activity and academic performance has been studied in various adolescent populations in different countries. For instance, data from public schools in the northeastern United States confirmed a positive correlation between physical fitness test scores and pass rates in math and English course assessments (Chomitz et al., 2010). Moreover, middle school students who met the aerobic endurance running standards not only had a higher likelihood of meeting standardized test benchmarks but also demonstrated improved academic performance (Bass et al., 2013). In Spain, after controlling for BMI z-scores, waist circumference, and body fat percentage, the levels of aerobic fitness and motor skills were positively correlated with the grades on math and language tests among 6–18-year-old adolescents (Esteban-Cornejo et al., 2014). Similarly, in Japan, cardiorespiratory fitness and overall health-related fitness were found to have significant positive effect on academic performance among middle school students (Ishihara et al., 2018). Meanwhile, in a study involving 183 college students examining the relationship between physical fitness and academic performance, it was found that, apart from body mass index (BMI), all students' physical fitness tests showed a significant positive correlation with average academic scores, indicating that high levels of physical fitness contribute positively to academic success (Başkurt et al., 2020). Zhang (2022) further investigated the factors influencing physical fitness scores among college students and identified physical fitness level, exercise frequency, and physical injuries as key factors. Currently, there is a contentious debate in the academic community regarding the apparent association between physical activity and academic performance due to varying research methodologies and data sources employed (Rodriguez et al., 2020).

In addition to the correlation and predictability of physical exercise on academic performance, some previous research has incorporated social cognitive theories from psychology to explain the underlying mechanisms. This suggests that the enhancement of students' cognitive abilities through physical activity primarily manifests in self-control, specifically focusing on self-regulatory efficacy (Anderson et al., 2006). The impact of self-efficacy on self-regulation and its association with exercise are highlighted, with self-regulatory efficacy positively correlated with exercise intensity (Bauman et al., 2012). This explanation aligns well with social cognitive theory, as identifying oneself as an exerciser is, to some extent, influenced by past exercise experiences and serves as a source of self-efficacy (Bandura, 1997). Moreover, achieving the desired intensity of exercise is associated with various behavioral outcomes related to academic development (Strachan and Whaley, 2013), including weekly exercise minutes (Strachan et al., 2010), weekly exercise frequency, duration and intensity of vigorous exercise (Strachan and Brawley, 2008), and the number of weeks engaging in exercise (Anderson et al., 1998). These studies indicate a correlation between exercise intensity and self-regulation. Therefore, the question arises as to which specific aspect of cognitive processes in adolescents may be impacted by physical exercise and how exactly it influences cognition. Current research has only scratched the surface by exploring certain facets of cognitive processes, and the studies conducted thus far remain fragmented (Balk and Englert, 2020).

In the study of the mechanisms underlying the impact of physical activity on academic performance, two approaches are commonly used: examining the mediating variables in the causal pathway between the two factors and exploring the underlying mechanisms from other disciplines such as psychology and cognitive science. The former approach, as proposed by Kayani et al. (2018), was "physical activity → self-esteem → learning motivation and performance," which suggests that the strongest mediator between physical activity and academic performance is self-esteem. To put it another way, physical activity could enhance students' self-esteem, which may serve as a guarantee for their motivation and academic success. Liang and Li (2020) explored the pathway of "physical activity → physical health → academic performance" by considering both explicit physical appearance and implicit physical skills as mediating factors. The scholars underscored the pivotal role of physical fitness as a significant mediating factor influencing academic achievement (Chacón-Cuberos et al., 2020; Koçak et al., 2021). The aforementioned studies illuminate the substantial correlation existing between psychological factors, physical well-being, and academic attainment. Specifically, factors such as self-control and low self-efficacy have been found to exert a significant influence on tendencies toward overeating, weight gain, and diminished physical fitness. As the volume of data utilized in sports research continues to grow, the expansive magnitude and complex nature of sports-related data necessitate enhanced data processing techniques.

In the field of sports research, there is an increasing inclination toward the utilization of non-linear data mining techniques. These approaches offer practical insights into associations between predictor variables (e.g., team performance indicators) and dependent variables (e.g., match outcomes) (Robertson et al., 2016). Unlike linear methods, these approaches can reveal multiple patterns within the data (Mandorino et al., 2021; Teixeira et al., 2022). One widely-used non-linear method is the decision tree, which partitions samples based on maximum information entropy (Mooney et al., 2017). Hijriana and Muttaqin (2016) applied decision trees to classify academic achievement, while You et al. (2018) used them to analyze physical activity's impact on hypertension prevention in middle-aged and older adults in China. Pei et al. (2019) evaluated five classifiers for identifying individuals with diabetes based on clinical features. Benediktus and Oetama (2020) employed the decision tree C5.0 classification algorithm, based on information entropy, to predict student academic performance and explore the role of student activeness as a predictor. The use of information entropy allows for a comprehensive exploration of intricate relationships and patterns within the complex system of physical activity (Silva et al., 2016). In this study, information entropy was also employed to construct indicators of activity patterns, with the aim of quantitatively assessing the uncertainty and randomness in the exercise patterns and trends of college students.

The progression of research involving the CHAID (Chi-squared Automatic Interaction Detector) method, in contrast to the commonly used decision tree algorithm, can be traced through multiple studies. Sanz Arazuri and de Leon Elizondo (2010) initially elucidated the application of hierarchical segmentation with CHAID, laying the foundation. Subsequently, Gómez et al. (2015) employed CHAID to pinpoint influential variables in ball screens, demonstrating its practical use. Building on this, Robertson et al. (2016) delved deeper, revealing distinctions between teams and showcasing CHAID's effectiveness in crafting performance indicator profiles. In a more recent study, Eagle et al. (2022) extended the research by utilizing CHAID for subgroup analysis and examining its role in assessing sport-related suicide risk. Throughout these studies, CHAID consistently displayed its potential in predicting behavior indicators and elucidating causal relationships, as underscored by Schnell et al. (2014), thus emphasizing its evolving significance in the field.

In the realm of academic inquiry, a contentious debate persists regarding the connection between physical activity and academic performance. This debate stems from the diverse research methodologies and data sources employed in previous studies (Rodriguez et al., 2020). Our research endeavors to contribute to this discourse by addressing several key objectives. Firstly, we aim to unravel the intricate relationship between physical activity and academic achievement among college students. we aspire to delve deeper into the impact of physical exercise on cognitive processes in adolescents. While prior research has touched upon this topic, our goal is to identify specific facets of cognition influenced by exercise intensity. Secondly, we recognize the need for advanced data processing techniques in sports research due to the complex and expansive nature of sports-related data. By embracing non-linear data mining methodologies and leveraging information entropy, we aim to offer a fresh approach to exploring intricate relationships and patterns within the realm of physical activity and its impact on academic achievement. Furthermore, we also aim to elucidate the interplay between psychological factors, physical well-being, and academic attainment. By focusing on variables such as self-control and self-efficacy, we intend to shed light on their significant influence on behaviors related to physical fitness. Our research seeks to provide a holistic perspective on student well-being and academic success. We focused on three principal research objectives:

- Q1: Is there a correlation between the data model constructed using behavioral indicators and academic performance?
- Q2: How can effectively uncover the factors that influence academic performance and attribute interpretability to physical activity metrics through the utilization of machine learning techniques?
- Q3: How can the establishment of a pathway depicting the factors of physical activity on academic performance aid in revealing the potential mechanisms?

Methods

Data source and preprocessing

The research data was gathered over a continuous 12-week period during one academic semester from undergraduate students at Sichuan International Studies University in China, with an average age of 19.08 years. The data was obtained from two different systems. Firstly, approximately 9,000 academic records, including the grades of three subjects and physical fitness test scores, were retrieved from the Educational Administration System. Secondly, the physical activity log data for the research subjects during the semester was extracted from a running app installed on their mobile phones, yielding approximately 34,000 records.

In the context of this study, the log data was distributed across various business systems, necessitating a series of preprocessing steps to fully harness the data's intrinsic value when constructing predictive indicators. Initially, the log data undergone anonymization and aggregation, involving the removal of sensitive information such as names, ID numbers, and phone numbers, followed by the correlation and integration of multiple datasets. Subsequently, common issues associated with log data, such as missing and imbalanced data, were addressed. Specifically, post-aggregation data undergone cleansing and adjustments. For instance, approximately 3.5% of students lacked running data, and there existed an imbalance in the gender ratio at college (male-to-female ratio: 1:4.3). Hence, during the preprocessing stage, missing data were addressed by eliminating invalid and duplicate records. Additionally, for datasets exhibiting skewed distributions, a Stratified Sampling approach was employed for female students to reduce the sample size, while a Bootstrap method was applied to male students to augment the sample size. This adjustment resulted in a more balanced male-to-female student data ratio of approximately 1:1.5, ensuring the integrity and validity of the predictive dataset. Ultimately, following data processing, a sample of 2,129 students was retained for the purposes of this research.

Physical behavioral indicators

Behavioral indicators are input datasets used for machine learning modeling. Wearable sports monitoring devices or mobile apps are applied to quantify various parameters and indicators of individuals and even groups, such as movement trajectories, exercise habits, energy expenditure, and health status. There are two main types of behavioral indicators: demographic indicators and behavioral indicators. Demographic indicators include basic personal information about students, such as age, gender, and major, which have good predictive capabilities in the early stages of learning activities which represent static data (Whitener, 1989). Behavioral indicators, on the other hand, encompass changing data generated during learning activities, such as activity frequency, duration and speed. These indicators exhibit better predictive effects in the middle and later stages of activities (Hussain et al., 2018; Karthikeyan et al., 2020), representing dynamic data. The research primarily investigates students' behavioral performance, specifically the impact of dynamic indicators on academic performance. Hence, in the construction of the analytical model, performance indicators pertaining to physical exercise are carefully chosen. Subsequently, directional indicators are employed to visually represent and classify the findings, thereby providing an effective means to elucidate the observed outcomes.

The utilization of information entropy in constructing an activity regularity indicator for college students aims to quantitatively measure the uncertainty and randomness pertaining to their exercise patterns and trends. Information entropy plays a vital role in the analysis of intricate systems in sports research, providing researchers with quantitative measures to assess and analyze various aspects of complex sports systems (Rhea et al., 2011). For instance, the utilization of entropy measurements in team sports has exhibited considerable potential in evaluating the uncertainty pertaining to players' spatial distributions, dominant regions, and various collective team behaviors (Silva et al., 2016). Additionally, entropy has been employed to analyze the complexity and information content of heart rate variability as an indicator of activity (Namazi, 2021). In this study, entropy measures have been employed in investigating the variability of performance to unveil the underlying interactions governing activity regulation among college students, and the indicator Hx was calculated based on the distribution of exercise frequency. The entropy value was computed using the proportion of the number of exercise sessions on days for one student out of the total number of exercise sessions over days. The Hx indicator codes and descriptions are presented in Table 1.

Physical behavioral indicators in current study were constructed based on the key indicators of the Physical Activity Readiness Questionnaire (PAR-Q). These indicators were developed from three aspects: exercise intensity, duration, and frequency (Thomas et al., 1992; Liang, 1994; Shephard, 2015). PAR-Q is widely used to assess physical activity levels. By scoring the three dimensions in the questionnaire, the individual's exercise volume is calculated using the formula "intensity * duration * frequency = exercise volume." This study built exercise indicators reflecting students' physical activity (running) over a 12-week period in one semester. These indicators included distance covered (in meters), average step frequency (steps per minute), average pace (meters per minute), running duration (in seconds), exercise regularity, and frequency. Among them, distance, step frequency, and pace reflected exercise intensity; running duration reflected exercise time; exercise regularity and frequency reflected

TABLE 1 Descriptive characteristics of physical activity behavioral indicators and academic achievement indicators.

Dimension	Variable	Code	Data range	Description
Physical activity behavioral indicators	Distance covered (meters)	D_X	592–7,413	The average distance (in meters) covered by students per running session during the 12-week semester
	Average step frequency (steps/min)	F_X	41.7–193.1	The average frequency of running sessions per week for students during the 12-week semester
	Average running speed (meters/min)	S_X	4.2–11.3	The average speed (in meters per minute) of students during each running session over the 12-week semester.
	Average running duration (seconds)	T_X	328–3,415	The average duration (in seconds) of each running session for students over the 12-week semester
	Activity regularity	H_X	0–1	The regularity of exercise H_X was calculated based on the distribution of exercise frequency. The entropy value was computed using the proportion f_j^m of the number of exercise sessions on the *jth* day for the *mth* student out of the total number of exercise sessions over *n* days. The formula for the calculation is as follows: $H_X = -\frac{1}{\ln(n)}\sum_{i=1}^{n} f_j^m \ln\left(f_j^m\right)$ (Formula 1)
	Activity frequency	V_X	1–43	The total number of running sessions in the 12-week semester was determined.
Academic achievement indicators	Academic performance score (AP)	AP	23–98.7	The formula for calculating AP is as follows: f_i denotes the final exam score for the *ith* major-specific course, and the weight is determined based on the credit value g_i of the course. This weight is used to calculate the weighted average score for the student's major courses. $AP = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{g_i}{\sum_{i=1}^{n} g_i} \times f_i\right)$ (Formula 2)

exercise frequency. The specific indicator codes and descriptions are presented in Table 1.

Academic achievement indicators

Academic performance (AP) indicators, are influenced by a number of factors such as teacher subjectivity, selection bias, and student behavior (Marques et al., 2018). Scholars commonly employ standardized tests to assess AP. Examples include the Academic Aptitude Test (SAT) in the United States, the National High School Examination (ENEM) in Brazil, and the General Scholastic Ability Test (GSAT) for higher education admission in Taiwan. Some researchers also use final grades from common courses and major-specific courses within the students' respective schools as indicators of academic performance. In the current study, the physical fitness scores and standardized average scores from major-specific courses of first-year university students over one semester were used as predictive targets to evaluate their physical fitness and academic performance. As for the selection of major-specific scores, due to the large sample size and the variation among students' colleges and majors, AP was primarily determined by the average scores of their highest credit courses. The conversion method is detailed in Table 1.

Data mining based on machine learning

In order to enhance the interpretability of the study's predictions, the target variables for prediction were not the conventional classification categories such as "pass," "good," and "excellent," but rather continuous variables directly associated with academic performance scores. This choice transformed the task into a typical regression problem. The study had two main parts: firstly, the data collected from the administration system and mobile apps are anonymized, aggregated, and cleaned, and the predictive variables for correlation and variance inflation factor (VIF) to identify the optimal predictors. Secondly, the CHAID decision tree algorithm was utilized for significance testing and branch prediction, providing statistical explanations and attributions to the results, and identifying potential factors influencing academic performance from the patterns of physical activity behavior among college students. The flowchart involving data collection, preprocessing, screening process, and data model construction, and CHAID decision tree modeling is shown in Figure 1.

Data model

To validate and compare the predictive capabilities of physical behavioral indicators on academic performance, the behavioral dataset was divided into two subsets. Both subsets were associated with the predictive target variables of academic performance, forming the learner data models Model 1 and Model 2, as follows. These data models served as the data source for subsequent prediction model construction and performance comparison.

Model 1: Physical behavioral indicators (Variables) - > Academic Performance Score (All Target).

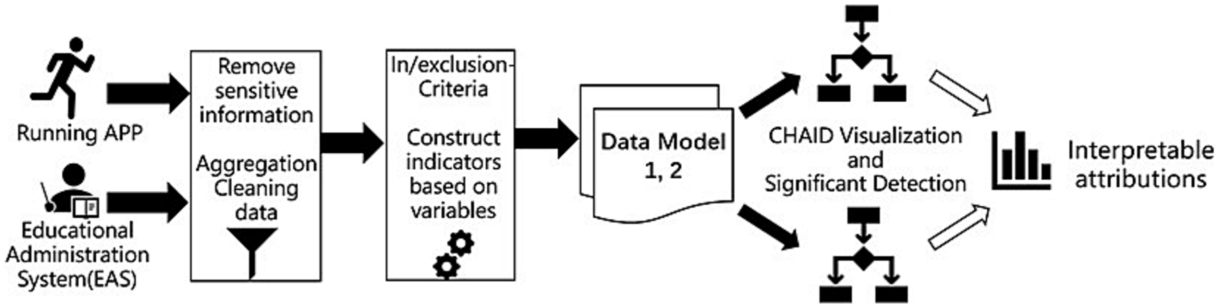

FIGURE 1
Flowchart of data mining based on physical activities.

Model 2: Physical behavioral indicators (Variables) - > Academic Performance Score (Only AP > 80).

Analysis tools

The predictive tools employed in this study utilized prediction algorithms provided by machine learning models, specifically SPSS Modeler for predictive modeling and analysis. The CHAID module in SPSS Modeler was used for decision tree visualization modeling. This module is used for branch prediction and significance analysis in the two data models. By utilizing the CHAID method, we could quickly and effectively unearth the primary influencing factors. This approach could handle nonlinear and highly correlated physical behavioral data. Furthermore, it could accommodate missing values, thus overcoming restrictions faced by traditional parametric tests in these aspects.

Results

Correlation analysis

Correlation analysis and variance inflation factor (VIF) tests were conducted on the behavioral indicators. The former assessed the phenomenon correlation between the predictive indicators and the target variable, while the latter evaluated the collinearity among the indicators within a controllable range. If the VIF value was less than 0.1 or greater than 10, it indicated poor predictive performance and necessitates adjustment or removal of the respective indicator (as shown in Table 2). From Table 2, it can be observed that the average running speed (S_X) has a relatively high VIF value, but it still falls within a reasonable range. All other indicator VIF values are less than 3, indicating that all predictive indicators satisfy the collinearity condition and should be retained.

Impact of exercise performance indicators on academic performance from data model 1

The analysis of academic performance was conducted based on the indicators from data model 1, as shown in Figure 2.

From Figure 2, it is evident that exercise regularity significantly influences academic performance ($p < 0.00$). In Node 2, 70% of students exhibited exercise regularity ranging from 0.488 to 0.753. These students, as long as they maintain good exercise regularity, can achieve satisfactory academic performance (AP = 79.951, comparable to the overall average of 79.553). Within the subset of students with higher exercise regularity, some individuals (Node 6) not only demonstrate regular exercise habits but also fulfill the designated running distance (Dx > 2731.63), resulting in above-average scores (AP = 80.896). The highest score is observed in Node 7, where students with the best exercise regularity (Hx > 0.796) and not necessarily fast running or high step frequency ($F_X > 155.13$) achieve the best academic performance (AP = 78.0). It is the students who exhibit regular, slower-paced, and lower step frequency exercise patterns that excel in academic performance.

Impact of exercise performance indicators on academic performance from data model 2

When investigating the impact of exercise frequency and duration on academic performance, no significant differences were found in the decision tree analysis among all study subjects ($p > 0.05$). Therefore, the study sample was reduced, focusing primarily on students with good academic performance (AP > 80). From a total of 2,129 occurrences, 1,468 individuals (accounting for 68.9%) were selected as the new sample for further analysis, as depicted in Figure 3.

Based on Figure 3, it was evident that exercise frequency had a significant impact on achieving better academic performance ($p < 0.00$). As the number of exercise sessions (V_X) increased from 8 to 10, academic performance also increased from 80.01 to 82.46, exhibiting a linear correlation trend. Among the majority of students (65.6%), exercise frequency exceeded 10 sessions ($V_X > 10$). However, it was not the duration of each running session that determined the academic performance; instead, students (12.057%) with an average running time between 982.17 and 1555.33 s (16.4–26.1 min) achieved the best academic performance (AP = 83.632). Additionally, within this group of students, 44.69% had a running duration of less than 16 min, indicating relatively shorter running times and only meeting the minimum requirements. On the other hand, a small percentage (8.86%) of students had an average running time exceeding 26 min, indicating slower running speeds, primarily jogging or even walking,

TABLE 2 Descriptive statistics, correlations, and VIF between physical behavioral indicators and academic achievement indicators.

Variable	M	SD	1	2	3	4	5	6	7	8
1. Age	19.08	0.776	–							
2. T_X	1389.370	366.333	0.012	–						
3. D_X	2997.380	752.255	0.041	0.875**	–					
4. F_X	132.742	26.929	0.025	−0.164**	−0.082**	–				
5. S_X	7.707	0.917	−0.063**	0.360**	−0.107**	−0.207**	–			
6. H_X	0.649	0.136	−0.051*	−0.240**	−0.306**	0.040	0.085**	–		
7. V_X	12.130	3.982	−0.042	−0.488**	−0.520**	0.089**	0.007	0.513**	-	
8. AP	81.944	6.210	−0.0076	−0.002	0.048*	−0.027	0.010	0.090**	0.097**	–
VIF	–	–	–	1.416	2.883	1.061	8.909	1.37	1.731	–

$N = 2{,}129$; *M*, mean; SD, stanfard deviation; VIF, variance inflation factor; $^*p < 0.05$; $^{**}p < 0.01$.

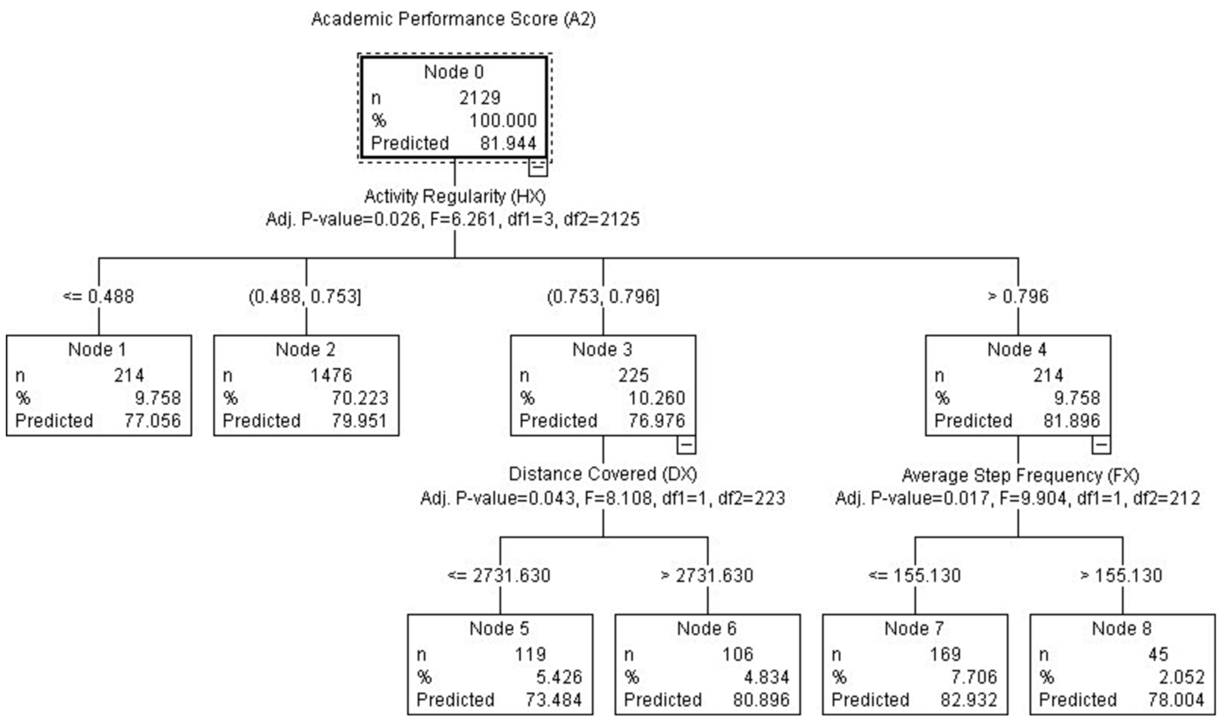

FIGURE 2
CHAID decision tree analysis diagram based on data model 1.

and insufficient intensity for cardiovascular exercise. Nodes 4 and Node 6 demonstrated a threshold effect, displaying an inverted U-shaped trend. While these students can also achieve satisfactory academic performance (AP > 82), their overall exercise effectiveness was inferior to that of students in Node 5, which exceeded the academic performance of approximately 88% of all other students.

Discussion

The effect of activity tasks on academic performance

In our academic endeavor, we undertook a correlation validation analysis to address the first research question (Q1) and utilized the CHAID methodology to identify the most substantial influencing factors in addressing the second research question (Q2). In terms of academic performance, students who successfully complete assigned tasks may achieve satisfactory average grades. However, to attain higher academic performance (AP = 82.932), as depicted in Node 7 of Figure 2, students not only need to demonstrate excellent activity regulation ($H_X > 0.796$) but also maintain a lower stride frequency ($F_X < 155.13$). This implies that students predominantly engage in jogging or walking, indicating lower exercise intensity compared to students in Node 8. It can be inferred that consistent engagement in low-intensity running promotes regular and sustained physical activity, indirectly affirming the endurance training component of exercise. This contributes to the development of students' self-control and self-efficacy, which in turn aligns with their academic performance. In the academic domain, students are encouraged to cultivate a mindset of continuous learning

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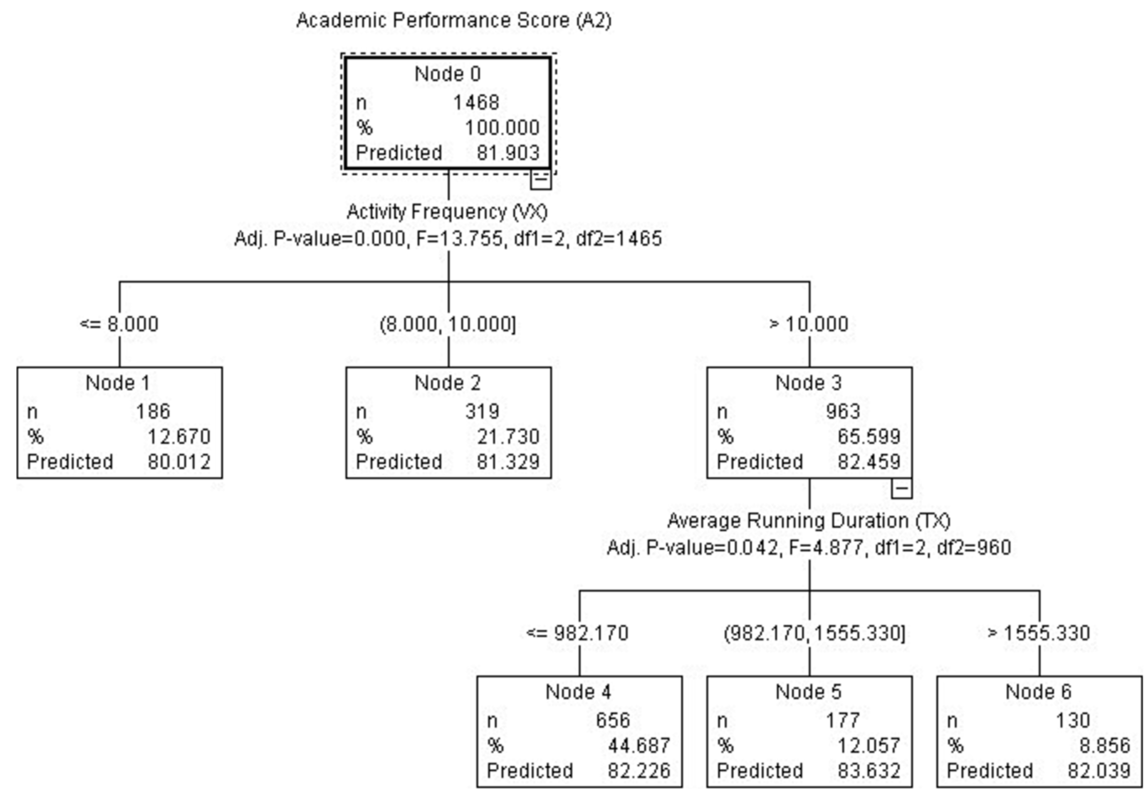

FIGURE 3
CHAID decision tree analysis diagram based on data model 2.

and steadfastness, rather than relying solely on intense and short-term bursts of studying. It is through consistent effort and perseverance that students can build a solid foundation of knowledge and skills, enhancing their academic achievements in the long run. By integrating regular physical activity into their routines, students not only improve their cardiovascular and aerobic fitness but also develop important qualities such as discipline, focus, and resilience, all of which are conducive to academic success. This highlights the significance of maintaining a balanced approach to both physical exercise and academic pursuits, recognizing the synergistic relationship between the two domains. Therefore， emphasizing the value of consistent and moderate exercise contributes to the overall well-being and holistic development of students, ultimately benefiting their academic endeavors.

Optimal activity frequency and duration for academic performance

During the exploration of second research question (Q2), we sought to unravel the factors that exert a substantial influence on academic performance and simultaneously imbue interpretability into the realm of physical activity metrics, leveraging the capabilities of machine learning techniques. In pursuit of this objective, we turned to the CHAID method, a powerful tool that allowed us to identify and highlight the most pivotal influencing factors. According to Figure 2, 67% of college students engage in physical activity with a frequency ranging from 7 to 14 times over the course of 12 weeks, which yields the maximum improvement in AP. Furthermore, 44.29% of students participate in physical activity between 10 and 14 times (at least once per week on average), resulting in favorable academic achievements (AP > 82). According to Figure 3, students who engage in physical activity for durations ranging from 16 to 26 min demonstrate the highest predictive capability for academic performance. Although the proportion of these students in Node 5 is not high (12.06%), it reflects the positive impact of physical activity on improving cardiorespiratory endurance and regulating self-efficacy. Considering the average running distance, most students have covered over 2 kilometers after running for 16 min, which is a critical period for cardiorespiratory/aerobic fitness (C/AF) development. These students are capable of maintaining a moderate pace during running without rushing to complete the distance task. Their awareness of self-regulation efficiency influences goal selection, persistence in goal achievement, and response to setbacks, thereby enhancing their self-regulatory abilities (Maddux et al., 2012). Allocating up to an additionally approximate half hour per day of curricular time to AP program does not affect the academic performance of primary school students negatively, even though the time allocated to other subjects usually shows a corresponding reduction.

Mechanism underlying the impact of physical activity on academic performance

To address research question (Q3), which pertains to elucidating the potential mechanisms by which establishing pathways may be beneficial, our study furnishes evidence for a mediating pathway within the impact mechanism. Specifically, we propose the pathway as follows: "physical exercise → self-control ability → academic performance." The self-control ability is derived from college students engaging in low-intensity running during physical exercise, which allows them to control their speed without rushing to reach their fitness goals while still achieving the required intensity. It also supports the findings of Xu et al. (2018), who concluded that executive function serves as an intermediate variable by which physical exercise promotes academic performance, explaining the pathway as "physical exercise → executive function → academic performance." Furthermore, physical exercise offers the advantage of being regularly and consistently performed on a weekly basis, thus enhancing college students' confidence and self-efficacy. This finding further corroborates with the research conclusion of Anderson et al. (2006) that while exercise directly influences academic performance, psychological-social factors and physical fitness levels play a mediating role. Through the expenditure of body fat calories during exercise, college students enhance their self-control ability and willpower, representing a self-regulatory structure that impacts individuals' efforts to maintain consistency between cognition and behavior (Anderson et al., 2006).

Data mining in sport education research

Physical activity involves complex decision-making processes, necessitating the utilization of effective tools and techniques to support physical educators. In the context of physical education research, it is essential to continuously explore the utilization of various research and experimental tools in practical investigations, fostering the in-depth application of advanced quantitative research methods and tools. In the domain of regression problems, it is imperative for machine learning algorithms to demonstrate not just robust predictive abilities, but also effective generalization. Therefore, in this study, the analysis extended beyond examining mean values of each indicator. To better capture the model's generalization and explanatory power, the CHAID decision tree was employed, enabling statistical significance testing and offering comprehensive regression results (Morgan et al., 2013). Decision trees, as a tool in machine learning have been playing a role in researching and solving complex problems in many fields, and has gained attention as a promising approach for tackling the intricacies and uncertainties associated with analyzing physical activity. Especially in the current era of big data, the abundance of data collected from observations of physical exercise (PE) and physical activity (PA) enables the emergence of behavioral patterns. By leveraging machine learning tools and statistical methods, the processing validity and reliability of physical observation data in complex systems can be improved (Robertson and Joyce, 2015). This serves as the material foundation and underlying logic for educational data mining and data-driven approaches, which are essential for enhancing educational management and informed decision-making. For instance, unsupervised learning methods can be employed to classify or cluster groups based on sports-related data using entropy-based techniques (Rhea et al., 2011; Namazi, 2021; Yang, 2021).

Limitations

First, this study leveraged a sizable sample for evaluating academic performance in relation to physical activity. Our research demonstrated an approach to enhance the interpretability and effectiveness of decision trees in processes. The challenges pertaining to missing physical exercise data, overfitting during model construction, and optimization of model parameters are to be addressed. Secondly, participants' levels of physical activity may not be fully reflected in the data obtained from the running application (APP) since some special cases may have not been excluded completely, where low physical activity values could be due to student dropout or illness-related leaves and exceptionally high values could be attributed to student athletes or long-distance running enthusiasts (Lupo et al., 2017a). Thirdly, university students may engage in physical exercise for varying objectives, such as medals, participation in competitive events or improving their academic performance. Therefore, future research will delve further into the motivations behind physical exercise and their direct or indirect (mediating) impact on academic performance (Lupo et al., 2017b; Liang and Li, 2020).

Conclusion

This study utilized machine learning methods to investigate the impact of physical activity on academic achievement among undergraduates. The decision tree model effectively captured the relationship between physical and academic performance. Activity regularity exhibited varying degrees of influence on the interaction between physical test scores and academic achievement, and explaining the relationship between physical activity and academic achievement in terms of psycho-social factors and physical fitness level. These findings contribute to the existing literature on the subject and provide insights for educational practitioners to enhance academic performance through physical activity interventions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Sichuan International Studies University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

SD: Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. HH: Supervision, Writing – review & editing. KC: Investigation, Validation, Writing – original draft, Writing – review & editing. HL: Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Anderson, D. F., Cychosz, C. M., and Franke, W. D. (1998). Association of exercise identity with measures of exercise commitment and physiological indicators of fitness in a law enforcement cohort. *J. Sport Behav.* 21, 233–241.

Anderson, E. S., Wojcik, J. R., Winett, R. A., and Williams, D. M. (2006). Social-cognitive determinants of physical activity: the influence of social support, self-efficacy, outcome expectations, and self-regulation among participants in a church-based health promotion study. *Health Psychol.* 25, 510–520. doi: 10.1037/0278-6133.25.4.510

Balk, Y. A., and Englert, C. (2020). Recovery self-regulation in sport: theory, research, and practice. *Int. J. Sports Sci. Coach.* 15, 273–281. doi: 10.1177/1747954119897528

Bandura, A., (1997).*Self-efficacy: the exercise of control*. Freeman Press, New York, NY.

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., and Martin, B. W. (2012). Correlates of physical activity: why are some people physically active and others not? *Lancet* 380, 258–271. doi: 10.1016/S0140-6736(12)60735-1

Başkurt, Z., Başkurt, F., and Ercan, S. (2020). Correlations of physical fitness and academic achievement in undergraduate students. *J. Phys. Educ. Hum. Move.* 2, 9–20. doi: 10.24310/JPEHMjpehm.v2i1.6770

Bass, R. W., Brown, D. D., Laurson, K. R., and Coleman, M. M. (2013). Physical fitness and academic performance in middle school students[J]. *Acta Paediatr. Scand.* 102, 832–837. doi: 10.1111/apa.12278

Benediktus, N., and Oetama, R. S. (2020). The decision tree c5. 0 classification algorithm for predicting student academic performance. *Ultimatics: Jurnal Teknik Informatika* 12, 14–19. doi: 10.31937/ti.v12i1.1506

Chacón-Cuberos, R., Zurita-Ortega, F., Ramírez-Granizo, I., and Castro-Sánchez, M. (2020). Physical activity and academic performance in children and preadolescents: a systematic review. *Apunts. Educación Física y Deportes* 139, 1–9. doi: 10.5672/apunts.2014-0983.es.(2020/1).139.01

Chomitz, V. R., Slining, M. M., McGowan, R. J., Mitchell, S. E., Dawson, G. F., Hacker, K. A., et al. (2010). Is there a relationship between physical fitness and academic achievement? Positive results from public school children in the northeastern United States. *J. Sch. Health* 79, 30–37. doi: 10.1111/j.1746-1561.2008.00371.x

Colley, R.C., Garriguet, D., Janssen, I., Craig, C.L., Clarke, J., and Tremblay, M.S., (2011). Physical activity of Canadian adults: accelerometer results from the 2007 to 2009 Canadian health measures survey (no. 82-003-X). Retrieved from statistics Canada Canadian Centre for Health website. Available at: http://www.statcan.gc.ca/pub/82-003-x/2011001/article/11396-eng.htm

Eagle, S. R., Brent, D., Covassin, T., Elbin, R. J., Wallace, J., Ortega, J., et al. (2022). Exploration of race and ethnicity, sex, sport-related concussion, depression history, and suicide attempts in US youth. *JAMA Netw. Open* 5:e2219934. doi: 10.1001/jamanetworkopen.2022.19934

Esteban-Cornejo, I., Tejero-González, C. M., Martinez-Gomez, D., del-Campo, J., González-Galo, A., Padilla-Moledo, C., et al. (2014). Independent and combined influence of the components of physical fitness on academic performance in youth[J]. *J. Pediatr.* 165, 306–312.e2. doi: 10.1016/j.jpeds.2014.04.044

Farrahi, V., Niemelä, M., Kärmeniemi, M., Puhakka, S., Kangas, M., Korpelainen, R., et al. (2020). Correlates of physical activity behavior in adults: a data mining approach. *Int. J. Behav. Nutr. Phys. Act.* 17, 1–14. doi: 10.1186/s12966-020-00996-7

Gómez, M. Á., Battaglia, O., Lorenzo, A., Lorenzo, J., Jiménez, S., and Sampaio, J. (2015). Effectiveness during ball screens in elite basketball games. *J. Sports Sci.* 33, 1844–1852. doi: 10.1080/02640414.2015.1014829

Hijriana, N., and Muttaqin, R. (2016). Penerapan metode decision tree algoritma c4. 5 untuk klasifikasi mahasiswa berprestasi. *Al-Ulum: J. Sains Teknol.* 2, 39–43. doi: 10.31602/ajst.v2i1.651

Hussain, M., Zhu, W., Zhang, W., and Abidi, S. M. R. (2018). Student engagement predictions in an e-learning system and their impact on student course assessment scores. *Comput. Intell. Neurosci.* 2018:6347186. doi: 10.1155/2018/6347186

Ishihara, T., Morita, N., Nakajima, T., Okita, K., Sagawa, M., and Yamatsu, K. (2018). Modeling relationships of achievement motivation and physical fitness with academic performance in Japanese school children: moderation by gender[J]. *Physiol. Behav.* 194, 66–72. doi: 10.1016/j.physbeh.2018.04.031

Karthikeyan, V. G., Thangaraj, P., and Karthik, S. (2020). Towards developing hybrid educational data mining model (HEDM) for efficient and accurate student performance evaluation. *Soft. Comput.* 24, 18477–18487. doi: 10.1007/s00500-020-05075-4

Kayani, S., Kiyani, T., Wang, J., Zagalaz Sánchez, M., Kayani, S., and Qurban, H. (2018). Physical activity and academic performance: the mediating effect of self-esteem and depression[J]. *Sustainability* 10:3633. doi: 10.3390/su10103633

Koçak, Ö., Göksu, İ., and Göktas, Y. (2021). The factors affecting academic achievement: a systematic review of meta analyses. *Int. Onl. J. Educ. Teach.* 8, 454–484.

Liang, Z., and Li, M. L. (2020). Progress of research on physical health promotion and academic performance of adolescent children. *J. Phys. Educ.* 27, 96–102. doi: 10.16237/j.cnki.cn44-1404/g8.2020.03.015

Liang, D. C. (1994). Stress levels of college students and their relationship with physical activity. *Chin. J. Ment. Health* 1, 5–6. doi: 10.3321/j.issn:1000-6729.1994.01.020

Lupo, C., Mosso, C. O., Guidotti, F., Cugliari, G., Pizzigalli, L., and Rainoldi, A. (2017a). The adapted Italian version of the baller identity measurement scale to evaluate the student-athletes' identity in relation to gender, age, type of sport, and competition level. *PLoS One* 12:e0169278. doi: 10.1371/journal.pone.0169278

Lupo, C., Mosso, C. O., Guidotti, F., Cugliari, G., Pizzigalli, L., and Rainoldi, A. (2017b). Motivation toward dual career of Italian student-athletes enrolled in different university paths. *Sport Sci. Health* 13, 485–494. doi: 10.1007/s11332-016-0327-4

Maddux, J. M. N., Schiffino, F. L., and Chang, S. E. (2012). The amygdala central nucleus: a new region implicated in habit learning. *J. Neurosci.* 32, 7769–7770. doi: 10.1523/JNEUROSCI.1223-12.2012

Mandorino, M., Figueiredo, A., Cima, G., and Tessitore, A. (2021). A data mining approach to predict non-contact injuries in young soccer players. *Int. J. Comp. Sci. Sport* 20, 147–163. doi: 10.2478/ijcss-2021-0009

Marques, A., Da, S., Hillman, C., and Sardinha, L. B. (2018). How does academic achievement relate to cardiorespiratory fitness, self-reported physical activity and objectively reported physical activity: a systematic review in children and adolescents aged 6-18 years. *Br. J. Sports Med.* 52:1039. doi: 10.1136/bjsports-2016-097361

Mooney, M., Charlton, P. C., Soltanzadeh, S., and Drew, M. K. (2017). Who 'owns' the injury or illness? Who 'owns' performance? Applying systems thinking to integrate health and performance in elite sport. *Br. J. Sports Med.* 51, 1054–1055. doi: 10.1136/bjsports-2016-096649

Morgan, S., Williams, M. D., and Barnes, C. (2013). Applying decision tree induction for identification of important attributes in one-versus-one player interactions: a hockey exemplar. *J. Sports Sci.* 31, 1031–1037. doi: 10.1080/02640414.2013.770906

Namazi, H. (2021). Complexity and information-based analysis of the heart rate variability (HRV) while sitting, hand biking, walking, and running. *Fractals* 29:2150201. doi: 10.1142/S0218348X21502017

Pei, D., Gong, Y., Kang, H., Zhang, C., and Guo, Q. (2019). Accurate and rapid screening model for potential diabetes mellitus. *BMC Med. Inform. Decis. Mak.* 19, 1–8. doi: 10.1186/s12911-019-0790-3

Rhea, C. K., Silver, T. A., Hong, S. L., Ryu, J. H., Studenka, B. E., Hughes, C. M., et al. (2011). Noise and complexity in human postural control: interpreting the different estimations of entropy. *PLoS One* 6:e17696. doi: 10.1371/journal.pone.0017696

Robertson, S. J., and Joyce, D. G. (2015). Informing in-season tactical eriodization in team sport: development of a match difficulty index for super Rugby. *J. Sports Sci.* 33, 99–107. doi: 10.1080/02640414.2014.925572

Robertson, S., Back, N., and Bartlett, J. D. (2016). Explaining match outcome in elite Australian rules football using team performance indicators. *J. Sports Sci.* 34, 637–644. doi: 10.1080/02640414.2015.1066026

Rodriguez, C. C., Camargo, E. M., Rodriguez-Añez, C. R., and Reis, R. S. (2020). Physical activity, physical fitness and academic achievement in adolescents: a systematic review. *Rev. Bras. Med. Esporte* 26, 441–448. doi: 10.1590/1517-8692202026052019_0048

Strachan, S. M., and Whaley, D. (2013). "Identities, schemas, and definitions: how aspects of the self influence exercise behaviour" in *Handbook of physical activity and mental health*. ed. P. Ekkekakis (New York: Routledge), 212–223.

Strachan, S. M., Brawley, L. R., and Spink, K. (2010). Glazebrook. Older adults' physically-active identity: relationships between social cognitions, physical activity and satisfaction with life. *Psychol. Sport Exerc.* 11, 114–121. doi: 10.1016/j.psychsport.2009.09.002

Strachan, S. M., and Brawley, L. R. (2008). Reactions to a challenge to identity: a focus on exercise and healthy eating. *J. Health Psychol.* 13, 575–588. doi: 10.1177/1359105308090930

Sanz Arazuri, E., and de Leon Elizondo, A. P. (2010). Key to applying the CHAID algorithm: a study of university physical-sport leisure activities. *Revista De Psicologia Del Deporte* 19, 319–333.

Schnell, A., Mayer, J., Diehl, K., Zipfel, S., and Thiel, A. (2014). Giving everything for athletic success! – sports-specific risk acceptance of elite adolescent athletes. *Psychol. Sport Exerc.* 15, 165–172. doi: 10.1016/j.psychsport.2013.10.012

Shephard, R. J. (2015). Qualified fitness and exercise as professionals and exercise prescription: evolution of the PAR-Q and Canadian aerobic fitness test. *J. Phys. Act. Health* 12, 454–461. doi: 10.1123/jpah.2013-0473

Silva, P., Duarte, R., Esteves, P., Travassos, B., and Vilar, L. (2016). Application of entropy measures to analysis of performance in team sports. *Int. J. Perform. Anal. Sport* 16, 753–768. doi: 10.1080/24748668.2016.11868921

Thomas, S., Reading, J., and Shephard, R. J. (1992). Revision of the physical activity readiness questionnaire (PAR-Q). *Can. J. Sport Sci.* 17, 338–345.

Teixeira, J. E., Forte, P., Ferraz, R., Branquinho, L., Silva, A. J., Barbosa, T. M., et al. (2022). Methodological procedures for non-linear analyses of physiological and behavioural data in football. *Exerc. Physiol.* 1, 1–25. doi: 10.5772/intechopen.102577

Whitener, E. M. (1989). A meta-analytic review of the effect on learning of the interaction between prior achievement and instructional support. *Rev. Educ. Res.* 59, 65–86. doi: 10.3102/00346543059001065

Xu, W., Zhang, Y., Zhou, L., Hua, J., School, E., University, Z. (2018). Influence of physical fitness on academic achievement in adolescents: evidences from a longitudinal study. *Journal of Beijing Sports University* 41, 70–76. doi: 10.19582/j.cnki.11-3785/g8.2018.07.010

Yang, B. (2021). Learning motivations and learning Behaviors of sports majors based on big data. *Int. J. Emerg. Technol. Learn.* 16, 86–97. doi: 10.3991/ijet.v16i23.27823

You, Y., Teng, W., Wang, J., Ma, G., Ma, A., Wang, J., et al. (2018). Hypertension and physical activity in middle-aged and older adults in China. *Sci. Rep.* 8:16098. doi: 10.1038/s41598-018-34617-y

Zhang, Y. (2022). An empirical study on the influence of college students' physical fitness on the level of public health. *J. Environ. Public Health* 8:8197903. doi: 10.1155/2022/8197903

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Effect of the hybridization of social and personal responsibility model and sport education model on physical fitness status and physical activity practice

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Physical activity patterns, sedentary habits and obesity levels among children and teenagers are indicators of a worrying reality which has been aggravated by the COVID-19 pandemic. In this context, this study has analysed the impact that new methodologies in Physical Education have on physical health aspects. Two teaching methods, namely, Teaching Personal and Social Responsibility and Sport Education Model, were hybridized, in a Secondary School in Murcia (Spain). Controlled quasi-experimental research was completed with a sample of 76 Secondary Education students aged 12–14 (male: 32; female: 44), developing a hybridization of both models in the experimental group. The *Physician-based Assessment and Counselling for Exercise* (PACE) questionnaire and Eurofit and Alpha Fitness motor tests were run to collect the results. Those showed significant improvement in standing long jump and speed-agility results in the control group. In the experimental group, on the contrary, no significant improvement was registered for either test, but out-of-school physical activity rates were higher. Following this research, it is concluded that both models have positive influence on physical activity habits, but the teaching time devoted to the subject of Physical Education is not enough to improve them.

KEYWORDS
health, secondary education, teaching methods, sedentary habits, teenagers

1. Introduction

Since the end of XX century, we have witnessed a struggle to incorporate health education in the Education field (Hurtado-García and Terrón-Bañuelos, 2022). As a matter of fact, Act 2/2006 of Education and Act 8/2013 for the Improvement of Education Quality established a specific block of contents which relates physical activity and health (Block IV. "Physical Activity and Health") inside the subject of Physical Education. Nowadays, the current law, Act 3/2020, which modified Act 2/2006, (hereon referred to as LOMLOE) includes basic knowledge specific to Physical Education which is related to active and healthy lifestyle.

This relationship is not whimsical as childhood obesity is a global epidemic and a very worrying disease (Saliba and Cuschieri, 2021). This alarming situation has been aggravated by the public health crisis induced by COVID-19 (Babu, 2022). In fact, new terms such as "covibesity" have appeared to refer to this situation (Bagherian et al., 2022). The lockdown during 2020 increased sedentary and inactive lifestyle habits which are among the most influential factors on high obesity levels (Blanco et al., 2019). Furthermore, in general terms, those factors are also motivated by aspects such as the impact of technologies and screen-based activities on leisure time (Lozano-Sánchez et al., 2019).

In Spain, obesity in childhood has been increasing during the last decades reaching alarming levels (De Bont et al., 2022). The main cause is the low physical activity levels that young people present but also other aspects as unhealthy eating habits complicate its eradication (Ramos-Pino and Carballeira, 2022). In Murcia, Carpena et al. (2023) affirm that the situation in Murcia is also worrying being necessary to change this dynamic promoting physical and sport activities in secondary schools in this region.

In this context, studies about obesity and sedentary habits have proliferated as they are more and more frequent among children, pre-adolescents and adolescents (Aparicio-Ugarriza et al., 2020; Jiménez-Parra et al., 2022). At the same time, it can be argued that Physical Education is a powerful resource to change this tendency. Currently in Spain, there are different programs, initiatives and studies (Lozano-Sánchez et al., 2019; Aparicio-Ugarriza et al., 2020) which have similar objectives: to motivate students to change lifestyle habits in curricular and extracurricular time. Some instances are "Active Breaks" which defends the positive relation between short periods of physical activity and concentration (Jiménez-Parra et al., 2022) and "Active Playgrounds" which tries to increase physical activity levels during break time at school, motivating students by creating spaces to play different games accessible for everybody, reducing the star role which balls have traditionally had (Salas-Sánchez and Vidal-Conti, 2020) Also in Spain, but with an international influence, it would be important to mention "Pasos Study" which deals with physical activity, sedentary lifestyle and obesity among Spanish youth, being one of the main goals to improve and increase physical activity levels among children and adolescents (Gómez et al., 2020; Wärnberg et al., 2021).

Besides that, as it can be read in the current Spanish education law (LOMLOE), physical activity has a main role in the subject of Physical Education, being one of the most important objectives to change students' inactive habits and developing a positive attitude to physical activity. To achieve this aim, it is necessary to consider the recommendation of World Health Organization (hereon referred to as WHO) in terms of physical activity. WHO defends that young people (5–17 years old) should practice 60 min of moderate-vigorous activity every day and spend, at least, 3 days per week doing 60 min of vigorous physical activity (World Health Organization, 2020).

Physical Education, however, was traditionally related to the quantitative development of physical capacities and sport skills and forgetting students' motivation (Burgueño et al., 2017). This factor added to the presence of technologies in children's lifestyle has caused students to reject sport practice and physical activity not only during Physical Education lessons but also in their leisure time (Hinojo Lucena et al., 2020). In view of this situation, the above-mentioned approach to Physical Education has proved ineffective, and it has been deemed necessary to work on new methods and strategies to increase the participation, motivation and involvement of students in an active way on Physical Education classes (Burgueño et al., 2017; Hinojo Lucena et al., 2020).

Sport Education Model (hereon, SEM) and Teaching Personal and Social Responsibility Model (hereon, TPSR) are two examples of this changing process (Bessa et al., 2019; Sánchez-Alcaraz et al., 2019). The first one, SEM, is focused on values related to "fair play" throughout sports. In this sense, the main goal is to offer an educational approach to sport, removing the excessive competitive spirit which characterizes institutional sport (Siedentop et al., 2004). Moreover, this model transfers the responsibility from teachers to students allowing them to manage the teaching–learning process development. Furthermore, SEM promotes some feelings and experiences such as the sense of belonging to the group or group cohesion (Calderón-Luquín et al., 2011), motivation and enthusiasm among teachers and students (Calderón-Luquin et al., 2010; Evangelio et al., 2018; Bessa et al., 2019) which are beneficial to students' holistic development. To meet those objectives, this model applies specific resources and strategies (Fernández-Rio and Menéndez-Santurio, 2017):

- To divide students into groups.
- To organize the syllabus design in "seasons" which last between 18–20 sessions.
- To create different competitions during each season.
- To assign roles to each member of the group related to the sport (referee, captain, doctor, …).
- To celebrate a final festivity in the last session with a ludic approach.

On the other hand, TPSR is based on social and personal values development through Physical Education (Hellison, 2011) promoting social and personal responsibility, both in Physical Education classes and in their daily life (Escartí et al., 2010a,b; Caballero-Blanco et al., 2013). This model evolves through a sequence of values which ranges from total irresponsibility towards the transfer of values in non-formal contexts (Hellison, 2011):

- Level 0: Irresponsibility
- Level I: Respect and self-control
- Level II: Participation and effort
- Level III: Self-direction
- Level IV: Leadership and caring
- Level V: Transfer

Throughout each level, TPSR develops social values (respect, teamwork and cooperation) and personal values (effort and personal autonomy). The sequence is developed through the sessions being aware that the objectives of each level should be achieved before moving on to the next level (Hellison, 2011; Sánchez-Alcaraz et al., 2019). In the subsection Methods, a deeper description of each element is provided.

A series of factors determined the choice of these two models for this study. It is undeniable that both methods offer high educational value as they contribute to the holistic education of students, overcoming the traditional conception of Physical Education as a field to develop just physical capacities and skills. TPSR and SEM have a potential to transfer values to students, especially responsibility and motivation to students in physical activity and sport context from the Physical Education class to their daily lives (Fernández-Rio and

Menéndez-Santurio, 2017). Nevertheless, that values are not developed by themselves in TPSR or SEM; it is necessary to guide the teaching–learning process, using methods, resources and strategies in line with those teaching models (Sánchez-Alcaraz et al., 2020). Both models have similar characteristics which can be combined to get the maximum of their possibilities (Fernández-Rio and Menéndez-Santurio, 2017; Bessa et al., 2019; Opstoel et al., 2020; Rodríguez et al., 2021; Sánchez-Alcaraz et al., 2021) as it will be explained in Method section.

In addition, both models approach the teaching–learning process based on motivational parameters which try to encourage students to do sport or physical activity outside school through positive experience in Physical Education classes (Escartí et al., 2010b; Fernández-Rio and Menéndez-Santurio, 2017). For this purpose, these models place students at the centre of the teaching–learning process, increasing their capabilities for building their own learning and for decision-making, thus improving their autonomy, motivation and participation in Physical Education classes (Opstoel et al., 2020).

Last but not least, this hybridization is common in the Education field as the combination of their characteristics is profitable for both models, being most of them complementary (Fernández-Rio and Menéndez-Santurio, 2017). Understanding hybridisation as the combination or fusion of different teaching–learning models, the characteristics of each one must be considered in a mixed way. In this sense, the methodology to be used should not be based on a single model but on a hybridisation, since the implementation of a single model does not allow to meet all the needs of the teaching–learning process (such as the content or the educational context) but the combination of different models allows to reduce this disadvantage (Evangelio et al., 2017).

There are several examples that have studied the application of both models and its influence on physical fitness levels and physical activity practice. One of them is the research developed by Sánchez-Alcaraz et al. (2021) in a context like this study, in which authors analysed the relation between the personal and social responsibility and physical activity levels on primary and secondary students at a high school in Murcia. In a similar way, also in Murcia, Gómez-Mármol et al. (2017) used a questionnaire to analyse the same relation. In Spain, there are other research as Fernández-Hernández et al. (2021) or Delgado-Floody et al. (2020) studies in which authors related physical activity levels in primary and secondary students with personal and social responsibility and other variables such as motivation. In all of those studies, results showed a positive influence on active and healthy habits.

Nevertheless, it is said that those models, especially TPSR, decrease motor engagement time as they use a vast amount of time in passive actions (meetings, organization, etc.) (Sánchez-Alcaraz et al., 2019; Salas-Sánchez and Vidal-Conti, 2020). For this same reason, short recent studies demand new proposals that hybridize teaching models which add motivational factors to physical activity and at the same time increase physical activity levels (Salas-Sánchez and Vidal-Conti, 2020).

There are also numerous studies that support the relationship between SEM and the increase in physical activity levels thanks to aspects such as improving motivation and predisposition towards the practice of physical activity (Valero-Valenzuela et al., 2020a). For example, Wallhead et al. (2014) analysed the influence of this model in relation to the motivation towards physical practice in the students' free time. After the application of the SEM, results showed greater motivation and greater predisposition towards the practice of physical activity in non-formal environments. However, these authors stated that, despite this greater provision, the application of the model did not guarantee an increase in physical activity during the leisure, with an appropriate extracurricular outlet being necessary. Along these same lines, Perlman (2010; 2012) also states that the application of SEM has a positive influence on the student motivation. In his study, in which he compared the application of a traditional methodology versus SEM, the author affirm that SEM favors the commitment of the student towards physical practice.

However, there are few publications which attend to physical activity levels or physical fitness status using the hybridization despite the positive results that this combination present (Hastie and Buchanan, 2000). In Spain, Lorente and Joven (2011) developed a research during 12 years proving a positive relation between both models and physical activity practice in extracurricular contexts. More recently, there are more examples that use the hybridization of SEM or TPSR with other levels such as Teaching for Understanding Games model (García-Castejón et al., 2021) or gamification (Melero-Canas et al., 2021).

Considering this context, the aim of this study was to analyse the effect that the hybridization of TPSR and SEM have on secondary education students' physical fitness levels and physical activity practice. The characteristics of both models were considered and hybridized, Eurofit and Alpha Fitness motor tests were implemented to assess physical fitness levels and PACE questionnaire was applied to assess physical activity practice, not only within the educational context but also out of it.

2. Materials and methods

2.1. Study design

Semi-experimental controlled research (own research) was carried out in a High School Centre in Algezares (Murcia, Spain) (Thomas et al., 2011). This school was selected by convenience, as the teacher leading the educational intervention was familiar with TPSR and SEM. The early-stage design was produced in cooperation with him to establish the working program because it had to adjust to the syllabus design for the subject. After he agreed, the head teacher and the principal of the high school gave their authorization. Legal tutors and students were duly informed about this intervention, and they also agreed to participate, by means of legal documents proposed by the Ethics Committee of University of Murcia (ID: 4117/2022). Furthermore, this Committee assessed the study design positively and allowed this pedagogical intervention.

2.2. Sample

This study was developed with 4 groups of second grade of Secondary School. At first, a group of 107 students were selected, but only 76 could fulfil the complete process. Results from students were deemed non-valid if (a) students had not complete pretest and/or post-test (b) students were absent from more than 3 sessions and/or

(c) students did not do a single test correctly – whether theoretical or practical.

Those 76 students, aged 12 to 14, (male: $n = 32$; female: $n = 44$) were randomly divided into a control group ($n = 36$) and an experimental group ($n = 40$) formed by class-groups. The former followed a traditional methodology while the latter put into practice the hybridization of TPSR and SEM. All of them had two Physical Education classes (60 min each) per week, using the same sports facilities (school indoor gym and an outdoor multisport court).

2.3. Instruments

The following instruments were used for data collection. These instruments have been widely used in scientific literature due to their high values of validity and reliability, low cost and easy application.

2.3.1. Physical activity

This variable was assessed through the questionnaire *Physician-based Assessment and Counseling for Exercise* (PACE) (Kolimechkov, 2017). This survey has two questions: the first one refers to the level of activity that a student normally does, and the second one aims at the specific physical activity level in a punctual sense (the past 7 days). Each question has only one possible answer (0–7) which represent the number of days per week. The questionnaire was completed in class just before and after the experiment, with the teacher present in the classroom. Students were allowed to ask questions after the explanation was concluded and there was no time limit. The results were kept anonymous.

2.3.2. Physical fitness

To analyse physical fitness levels, it was necessary to refer to samples from Eurofit and Alpha-Fitness battery of tests. Standing long jump, speed-agility and cardiorespiratory endurance tests were selected as the teacher had previously included those motor tests in his syllabus design so we used them not to interfere in the normal development of the subject. Eurofit standing long jump test together with Alpha Fitness cardiorespiratory endurance and speed-agility test were the ones selected to assess the students' physical fitness levels. All of them were applied the week before and the week after the intervention process both in control and experimental groups. Each test had some specific instructions:

1. Standing long jump test (Castro-Piñero et al., 2010): one by one, each students put their feet together behind a line marked by the teacher. When they were ready, they jumped as far as possible keeping their balance. After that, the distance was measured from the line to the student's heels.
2. Speed-agility test (Ortega et al., 2008): before the practice, a circuit was prepared using two cones and demarcating a 10 m distance between each one. The students had to begin behind the first cone. The teacher started a countdown, saying "three, two, one, go." When students heard "go" they started running as fast as possible touching each cone. They had to run to the second cone and back, five times in all.
3. Cardiorespiratory endurance (Liu et al., 1992): all the students started behind a line marked by the teacher. Before starting, the teacher explained that they were going to follow a recorded track which would give them instructions. Moreover, the teacher explained that they would have to run from the starting line to another line (located 20 m away) as many times as they could. They had to follow the recording which would indicate the moment when they had to stop and restart the run. If they reached the line after they heard the sound, the test was over for them.

Each motor test was explained beforehand in three different ways:

a) An oral explanation in class, emphasizing the key points and rules of each test.
b) Videos which allowed students to see how to act in each test.
c) A new oral explanation just before the motor test took place.

Along with the explanation of the tests, it was important to make students aware that it was not a competition, making emphasis on the importance of accuracy during their practice.

Before each test, the teacher led a warm-up process orientated to the specific motor test. After that, students had the opportunity to do each test twice, keeping the maximum mark.

2.4. Procedure

For 3 months (from January to March) and 17 sessions, the experimental group developed the hybridization of TPSR and SEM integrated into the school syllabus design. For that reason, sessions were organized in three teaching units which were based on three alternative games and sports:

- Teaching unit 1: based on Colpbol sport; 6 sessions. In this unit the aim was to develop respect and participating and effort which correspond to TPSR level 1 – spanning 4 sessions – and TPSR level 2–2 sessions. Those overlapped the first phase of SEM (presentation and introduction of model characteristics: roles, competition…) and also the second phase, namely preseason, which was based on practice directed by the teacher.
- Teaching unit 2: based on racket games; 6 sessions. It focused on TPSR level 2–2 sessions – and TPSR level 3, which dealt with personal autonomy – 4 sessions. This level concerned the autonomy of students, but the teacher made emphasis on respectful behaviours that had been worked on during the previous teaching unit. As for SEM, the second phase was completed, and third phase (*season*), based on competition, was developed.
- Teaching unit 3: based on Frisbee Ultimate sport; 7 sessions. The last teaching unit focused on TPSR level 4 – helping others – 4 sessions. The rest of the unit was programmed to reinforce previous TPSR levels. Regarding SEM, phase three was over and a final festivity was prepared and celebrated in the last session (phase 4).

On the other hand, the control group followed the same syllabus design, based on the same games and sports for the same period of time but putting into practice the traditional methodology proposed by the teacher. This methodology always observed the same session structure divided into three parts (Seners, 2001):

- First part (10–15 min): students went to the meeting point (locker room) where attendance was checked. After that, a warm-up routine was followed by students.
- Second part (30–35 min): at least three games or activities based on the arranged sport were played involving technique and tactic elements.
- Third part: (10–15 min): students developed a calm-down routine before returning to their reference classroom.

A unique teacher directed the teaching–learning process for both groups (control and experimental). The two syllabus designs were based on blocks I, II, and IV (Table 1) which were related to the following curricular elements (Ley Orgánica, 2013), (Ley Orgánica 8/2013, de 9 de diciembre, para la mejora de la calidad educativa (LOMCE), 2013):

2.4.1. Model hybridization

The process of hybridizing TPSR and SEM had to comply with specific curricular elements. The characteristics that were considered during the process will be outlined now so that the merge can be fully understood.

Regarding TPSR, there were two standing characteristics: values progression and session model (Hellison, 2011; Sánchez-Alcaraz et al., 2016; Fernández-Rio and Menéndez-Santurio, 2017).

- *Values* progression: the main objective of this model is to gradually develop personal and social values throughout systematic progression throughout the whole intervention process (Hellison, 2011). This progression includes 5 levels which correspond to respect (level 1), participation and effort (level 2), personal autonomy (level 3), helping others (level 4) and the last level which consists in taking responsibility out of the Physical Education class context (level 5).
- *Session structure*: every session was divided into four parts as it is established in this model (Menéndez and Fernández-Rio, 2017).
  - o The first part is related to the awareness process of each value which is worked on at that moment. This part normally lasts from 10 to 15 min, including the time for getting to the outdoor court or the gym and checking attendance, among other class routines. During this time, the teacher introduces the session aims related to values, using an informative poster, displayed permanently on the gym wall.
  - o The second part, "activity plan," is based on responsibility in action which means that students should put into practice the behaviours and attitudes explained by the teacher in part one. Therefore, for 25 to 35 min motor games and modified games are suggested, allowing students to learn the technique and tactic of each sport, as they ae given more and more responsibility for their own preparation using SEM roles together with autonomy practice, also typically of this second teaching model.
  - o The third part (from 10 to 15 min) consists of a meeting in which students discuss the most important elements and events which have taken place during the session. Students with referee roles direct an assembly sanctioning the behaviours which were against TPSR values and reinforcing the positive attitudes of their classmates.
  - o The last part is related with session assessment. For 2 min students individually draw conclusions from the previous part and assess the session using thumb test.

All these parts were organized into 60 min classes, including some time to go from the classroom to the court, to collect the material or to allow for students' personal hygiene. In addition, this fix structure improved responsibility-level results among students as they better acquire the routines thus feeling confident and motivated (Prochaska et al., 2003).

The second model in the tandem, SEM, is based on the sport teaching process focused on providing gratifying experience to students and understanding the concept of fair play as a key point (Carriedo et al., 2022). To achieve its goals, this model puts into practice different strategies and dynamics (Siedentop et al., 2004; Fernández-Rio and Menéndez-Santurio, 2017):

The teaching units are called "seasons" which have a longer duration than traditional units. This study comprised the development of only one season overlapping three teaching units (one per sport/game).

- Students are divided into stable teams. Each team should have the same number of students. In this case, it was necessary to form three slightly different groups per class (5–6 students).
- Each member of the group has a responsibility role which changes every three sessions. For this study, roles were *referee, assistant referee, captain, journalist, coach and assistant coach.* Each role has specific functions which must be displayed at all times, easily visible on the wall of the class and indoor gym (for instance, captain had to collect the material; coach and assistant coach had to receive instructions from teacher and explain them to their teammates; journalist had to write one 300-words article after each session, referees and assistance referees must control match development taking decisions considering rules …).
- Sports and games are modified to adapt motor situations to the possibilities and limitations of students. Some strategies to achieve that in this context were to adapt spaces, material or time

TABLE 1 Curricular framework (Decreto, 2015).

Block of contents	Content	Key competence	Stage objective
Block I. Physical fitness and health	Physical capacities development	Social competence	K
		Scientific competence	H
Block II. Games and sports	Knowledge of technique, tactic and rules of sports	Social competence	A, C
		Learning to learn	K
Block IV. Common elements	Rules acceptance and elaboration	Social competence	A, C
	Team-work and active participation	Social and learning to learn competences	B

or rules (for instance, when the experimental group was playing racket games, the ball could touch the ground more than once). Throughout these modified situations, technique and tactics are included as part of the teaching–learning process.

- Different competitions are developed during each season. Nevertheless, this model prescribes different scoring taking into account not only the conventional point system related to each sport, but also including aspects related to the values which have been introduced previously.
- At the end of the season, a final festivity takes place. Each team competes in a ludic atmosphere, celebrating the end of the season. Students were allowed to bring banners, to design equipment or to create a choreography to introduce the team before the competition.

3. Results

3.1. Physical activity

Table 2 shows the results obtained both in control and experimental groups concerning the number of days that students do physical activity in a normal week. In this sense, pretest results showed that 12.5% of control-group students did not do any exercise during a normal week, being 15% the students who did not do any exercise in the experimental group. In contrast, post-test results showed that 3 control-group students (7.5%) did not do physical activity in a normal a week while 2 (5%) experimental-group students chose this option, post-test results being lower than pretest results in both groups.

In the control group the highest percentage in pretest was associated with option "4 days per week" with a total of 9 answers (22.5%), while in the experimental group the maximum number of answers were divided into zero, two, four and 6 days per week with a total of six answer (15%) in each field. As regards post-test, in both groups, the highest percentage was associated with the answer "3 days per week" as 12 (30%) students selected this option in the control group and 9 (22.5) did in the experimental group. For both, this option obtained the highest mark attending to pretest and post-test results. There were no significant differences between control group and experimental group neither in pretest stage ($p = 0.748$) nor in post-test stage ($p = 0.996$).

Table 3 shows results referred to question 2, related to the number of days that the students had done physical activity in the previous week. Pretest results showed that 7 students (17.5%) from the control group said that they had not done any exercise during the previous week, this result being higher than the same option for Question 1. However, 3 students (7.5%) said that they had done physical activity every day in the previous week while in Question 1 only one student selected this option. Regarding the experimental group, it can be observed that 9 students chose option "4 days per week" in pretest while 11 students selected that option in post-test. The same table shows that in post-test the option "0 days per week" was selected by 1 student (2.5%), from the control group, this being the minimum percentage register. There were no significant differences between control group and experimental group neither in pretest stage ($p = 0.305$) nor in post-test stage ($p = 0.727$).

Table 4 shows that physical activity levels increased in the control group and experimental group if the results in pretest and post-test are contrasted. As it can be seen, the mean was superior in both questionnaires and in both groups. In fact, the differences between the results of the second questionnaire for the control group were significative ($p = 0.02$), this being a medium effect size (0.4) as the control group was formed by less than 50 people (Escartí et al., 2013).

However, data in Table 4 reveal that the experimental group did not experience any significant change comparing pretest and post-test results. Even though there were higher results regarding the number of days that students did physical activity, the effect size was small for Question 1 (0.2) and Question 2 (0.1).

3.2. Physical fitness

Table 5 displays results for control group and experimental group students in motor tests (speed-agility, standing long jump and cardiorespiratory endurance). Comparing both groups, it shows that the experimental group achieved superior pretest results except for speed-agility test. The control group started from lower pretest results but experienced an improvement in all categories results after the intervention. The experimental group obtained higher results in speed-agility (M = 8.80, SD = 1.14) and cardiorespiratory endurance

TABLE 2 Question 1. Physical activity level in a normal week (control and experimental group).

Days per week	Pretest *N* (%)		Post-test *N* (%)	
	Control	Experimental	Control	Experimental
0	5 (12.5)	6 (15)	3 (7.5)	2 (5)
1	4 (10)	3 (7.5)	2 (5)	2 (5)
2	4 (10)	6 (15)	7 (17.5)	7 (17.5)
3	6 (15)	4 (10)	12 (30)	9 (22.5)
4	9 (22.5)	6 (15)	3 (7.5)	7 (17.5)
5	6 (15)	4 (10)	7 (17.5)	4 (10)
6	5 (12.5)	6 (15)	3 (7.5)	2 (5)
7	1 (2.5)	1 (2.5)	3 (7.5)	3 (7.5)

TABLE 3 Question 2. Physical activity level in the previous week (control and experimental group).

Days per week	Pretest N (%)		Post-test N (%)	
	Control	Experimental	Control	Experimental
0	7 (17.5)	5 (12.5)	1 (2.5)	2 (5)
1	3 (7.5)	1 (2.5)	2 (5)	0 (0)
2	7 (17.5)	5 (12.5)	9 (22.5)	6 (15)
3	8 (20)	3 (7.5)	6 (15)	8 (20)
4	2 (5)	9 (22.5)	7 (17.5)	11 (27.5)
5	6(15)	7 (17.5)	5 (12.5)	5 (12.5)
6	4 (10)	4 (10)	6 (15)	1 (2.5)
7	3 (7.5)	2 (5)	4 (10)	3 (7.5)

TABLE 4 Physical activity levels.

Group	Number of days	Pretest (M ± SD)	Postest (M ± SD)	Z	P	d
Control	Normal week	3.32 ± 1.99	3.45 ± 1.89	−0.476	0.634	0.1
	Last week	3.10 ± 2.22	3.88 ± 1.90	−2.330	0.020	0.4
Experimental	Normal week	3.17 ± 2.16	3.58 ± 2.05	−0.756	0.450	0.2
	Last week	3.44 ± 1.81	3.67 ± 1.66	−0.077	0.938	0.1

TABLE 5 Differences between control and experimental group (pretest and post-test).

Test	Group	Control (M ± SD)	Experimental (M ± SD)	Z	p	d
Speed-agility	Pretest	9.16 ± 1.08	8.5 ± 0.76	−2.073	0.038	0.7
	Postest	9.38 ± 1.07	8.8 ± 1.14	−0.152	0.879	0.53
Standing long jump	Pretest	1.40 ± 0.25	1.65 ± 0.25	−2.508	0.012	1
	Postest	1.46 ± 0.25	1.58 ± 0.27	−1.360	0.174	0.46
Cardiorespiratory endurance	Pretest	1758.8 ± 368.76	2187.5 ± 418.4	−0.530	0.596	1
	Postest	1970.3 ± 1314.61	2210.38 ± 487.8	0.166	0.868	0.2

Effect size (Cohen's D).

post-test ($M = 2210.38$; $SD = 487.76$) but had a decrease in standing long jump test as it can be seen in Table 5 ($M = 1.58$; $SD = 0.27$).

Table 5 also shows that differences between the first and the second test were significant for the control group in the standing long jump test ($p = 0.01$) and the speed-agility test ($p = 0.04$). The same tests show non-significant differences in the experimental group in both categories ($p = 0.17$ and $p = 0.88$). Likewise, the cardiorespiratory endurance test proved no significant difference, neither in the control group ($p = 0.6$) nor in the experimental group ($p = 0.87$). Focusing on those differences, it is shown that a large effect size ($d = 1$) was obtained from calculating the average of control and experimental standing long jump and cardiorespiratory endurance pretest results. In the same way, speed-agility test showed a large effect size ($d = 0.7$) between control and experimental pretest results. On the other hand, post-test results did not show those differences, the largest effect size being the ones registered in speed-agility ($d = 0.53$) and standing long jump tests ($d = 0.46$), which represents a medium effect size. Finally, cardiorespiratory endurance post-test results showed a small effect size between the averages of both groups ($d = 0.2$).

4. Discussion

The main objective of this study was to analyse the influence that the hybridization of TPSR and SEM has on students' physical activity levels and physical fitness status. With that purpose, it was decided to analyse habitual and punctual physical activity using PACE questionnaire.

Regarding physical activity levels, it could be said that there was significant improvement in the control group activity levels (habitual and punctual) but not in the experimental group. Nevertheless, this second group also showed an increase on both results.

Those results go in line with previous research which showed non-significant results for the experimental group in this dimension after the application of SEM (Pérez-Pueyo et al., 2021). Despite the results obtained with PACE questionnaire, these authors affirm that physical activity levels improved applying SEM, as this model has a positive influence on other variables such as participation or sportsmanship. Perlman (2011) also affirm that the application of SEM has a positive influence in students' motivation. In the case of the application of TPRS, Gómez-Mármol et al. (2017) observe a relationship between increased accountability and improved levels of practice. Furthermore, in the work of Gómez-Buendía et al. (2022) they also conclude that both models (TPSR and SEM) and their hybridisation favour student enjoyment. Therefore, it can be considered that these variables encourage students' willingness to participate in physical activities and sports.

As well as this previous study, other research also defends the relation between the improvement of those variables and physical activity levels (Valero-Valenzuela et al., 2020b). In this study, which deals with different active models (SEM and gamification), authors justified this relation mentioning that the improvement of students' self-confidence and motivation rendered them more predisposed to participate in physical activities, not only in school but also in non-formal contexts. Pritchard et al. (2015) also affirm that a season of SEM has a positive impact on physical activity levels in non-formal contexts as their quantitative results showed better physical practice levels in students' spare time such as summer.

After Valero-Valenzuela et al. (2020b) and Kurt et al. (2017) interventions, significant improvements were obtained in terms of physical activity levels, which contrast with those of our study. Indeed, their study was different to ours, as they applied the hybridized model oriented directly to developing physical fitness using specific techniques for that purpose, whereas our current study used the hybridization developing different alternative sports to achieve that goal.

Considering another study, which analyse the influence of TPSR on physical activity levels, the improvement on dimensions such as personal and social responsibility proved to have an impact on students' perception of physical activity (Sánchez-Alcaraz et al., 2021). However, physical activity levels results were medium-low and there were no significant changes in any dimensions (punctual or habitual). In this sense, Hastie and Buchanan (2000) explain that the relation between this model and physical activity levels was indirect as the results and improvement were not only derived from the intervention itself, but also from the experiences or feelings such as enjoyment, task-involving and self-perception.

Consequently, it is important to emphasize that the results shown for both groups in our study allow us to understand that most of the students did physical activity 3 days per week, while the percentage of students who did exercise every day of the week as WHO recommends (World Health Organization, 2020) attained the minimum rate. In the light of that information, this study supports the current educational guidelines stating that all teachers should be able to encourage students to do sports and physical activity in their spare time. In fact, despite Physical Education being the specific area which deals with physical activity and health, this should be considered as transversal curricular content which should be included in each subject (Ley Orgánica, 2020), (Ley Orgánica 3/2020, de 29 de diciembre, por la que se Modifica la Ley Orgánica 2/2006, de 3 de Mayo, de Educación (LOMLOE), 2020).

Regarding physical fitness status, motor tests were run before and after intervention in both groups. On one hand, the control group produced better results after intervention, the difference being significant on standing long jump and speed-agility test. On the other hand, there were no significant improvements in the experimental group, which even showed a decrease in standing long jump test.

Those results might clash with a study based on physical activity (Pérez-Pueyo et al., 2021) which established a clear relation between the self-concept and self-confidence that an individual has and their physical activity level and physical fitness status. In addition, Carriedo et al. (2022) showed a direct relation between each dimension and the motor test results. They argue that motor tests in the educational field are influenced by personal self-confidence, and that is one of the elements which is worked on through the implementation of TPSR and SEM.

In fact, other research proved that SEM has a positive influence on the development of physical fitness throughout motor tests (Farias et al., 2018). Their authors defend that this kind of methodologies increase the motivational level and the interest in those motor tests. Moreover, Kurt et al. (2017) claim that this model allows students to discover their own possibilities and limitations increasing their confidence. However, this study did not actually test the quantitative results of motor tests.

Interestingly, better results in control group when applying physical fitness motor tests were also found in previous investigations (Rosa et al., 2019; Carriedo et al., 2022). There the control group students got better quantitative results in standing long jump, speed-agility and cardiorespiratory endurance tests as it happens in our study. The experimental group, however, showed a decreased in standing long jump test and non-significant improvements on cardiorespiratory endurance and speed-agility tests, similarly to the outcome reflected in our study.

The consistency of our results with the findings of Rosa et al. (2019) led us to reconsider and relativize our first hypothesis to explain them. Initially, the non-significant results in the experimental group were attributed to the public health crisis caused by COVID-19 pandemic. In Spain, during 2021, people who were infected by this virus had to stay at home for at least 10 days, as regulated by health authorities. This restriction meant that some students could not finish the study or could not complete all the sessions which were programmed. Other constrictions such as not sharing the material or not being able to touch each other also limited the normal course of the intervention.

However, these results could be pinpointing the fact that both models have some limitations that should be considered. Firstly, TPSR dedicates plenty of time to non-physical activities such as meetings, reflection or self-evaluation in each session. This could be a reason for not having better results in the experimental group as the main aim of this model is not related to the physical dimension of the human being. In the same way, SEM needs a vast amount of time for non-physical elements, such as organizing the competition, creating some material for the final festivity and holding meetings to resolve possible conflicts. This does not mean that the hybridisation of the two models is detrimental to motor development. This hybridisation considers the whole person and therefore focuses not only on the motor domain, but also on all other domains. In this sense, Pan et al. (2019) conclude that the hybridisation of TPSR-SEM increases learning in the motor, cognitive and affective domains. According to the authors, sport self-efficacy, passion for sport, responsibility and game performance improve.

Added to the limitation to the development of physical fitness which are inherent to the models chosen for the hybridization, and the non-inherent health restrictions in force at the time of the intervention, there was another factor which altered the course of the intervention as far as physical fitness development is concerned: unanticipated external agents such as weather. At this time of the year (January, February, and March) the practice of physical activity outdoors was difficult. On rainy days, it was not possible to use the uncovered court of the school where students have enough space to develop their physical skills comfortably, especially in sports such as Colpbol or Ultimate Frisbee. Instead of that, it was necessary to use the multiuse indoor gym which has rather limited space. To adapt to those conditions some alterations to the program were required. In this sense, Casado-Robles et al. (2020) point out that the improvement of physical fitness can depend on many factors, but it can have positive effects if there is adherence to the practice of physical activity. To this end, Segovia and Gutiérrez (2020) recommend programming the SEM model for a longer duration to encourage students to be physically active.

Finally, another aspect that could have influenced the results of our research both in terms of physical activity levels and physical activity status was the lack of time that this intervention had each week. Considering that this study is analysing healthy habits in students' daily life, and trying to improve them in most cases, 2 hours per week could arguably not be enough to change an unfavourable situation. In the same way, a previous study defends this idea that time devoted to Physical Education in Spanish educational system should be increased (Hastie and Buchanan, 2000; Pérez-Pueyo et al., 2021).

However, implementation of PACE questionnaire did not provide complete information about students' physical activity habits. Most of them said that they did activity at least 3 days per week, but data are not specific as to what kind of physical activity they referred to, differentiating between vigorous and moderate as WHO normally does. In addition, it would have been useful to know the physical activity context so as to learn more about those habits, taking into account, for instance, if students were engaged in out-of-school activities related to sports and exercise, if their practice was self-directed and informal, or if, on the contrary, they only did physical activity in Physical Education classes.

Another key factor was time. After this intervention we can ascertain that 2 h per week of Physical Education classes is not enough time to encourage students to do physical activity out of school and, even less to get them to do the amount of physical activity recommended by WHO. This research thereby supports the necessity to follow the current educational legal framework which reflects this situation establishing physical activity and health as transversal contents. Hence, it is not only Physical Education teachers' responsibility to encourage healthy habits, but it should also be considered as a collective issue for every agent involved in students' education and development.

In this sense, our research can shed light to the above-mentioned need in the education field. It is really important to use Physical Education as a source of motivation to encourage students to do physical activity in their free time and integrate that idea in other subjects too as transversal content. Our hybridization of TPSR and SEM obtained its most positive results when measuring the impact of our intervention in terms of physical activity frequency among our student sample, which in fact confirms previous research which have shown that using active methods in class such as SEM could have positive results in terms of motivation and physical activity levels in spare time (Spittle and Byrne, 2009; Merino and Mora, 2022) Thus from this study, it is considered appropriate to encourage teachers to apply those active methods and models to their own classes in order to comply with the current educational requirements and to encourage students to practice physical activity and sport in their spare time, considering physical activity as a means to instill physical, mental and social health. Moreover, by applying this hybridization during break-time through school-level organized competitions, schools would be directly palliating this disconnection between free time and physical activity among some of their students and bringing secondary school education closer to the guidelines recommended by WHO.

This research could be considered a pilot study that would be useful as a referent for further publications. As our study did not produce significant results, it is recommended to keep analysing this hybridization to get more results which relate the effect of TPSR and SEM to physical activity levels while still adhering to healthy habits as the main focus.

Future research might be able to provide deeper insight into the weaknesses of TPSR when applied to raise physical activity levels and physical fitness status so that they can be mitigated. Following bibliography, that mitigation would enhance the standing characteristics of SEM such as autonomy, participation in training and competition, and would allow us to reduce inactive time in Physical Education classes. For further investigations, it is also recommended to analyse the relation between the motivation parameters of SEM and

5. Conclusion

The effect that the hybridization of SEM and TPSR has on secondary education students' physical activity routines and fitness levels has been analysed in this study. Eurofit and Alpha Fitness motor test together with PACE questionnaire have been the tools implemented to obtaining the data for the research.

The study was motivated and justified by the current concern about teenagers and children's health and their growing tendency to choose sedentary activities in their free time – a concern which is acknowledged and reflected in Act 3/2020 (LOMLOE, 2020). The hybridization of those specific models, TPSR and SEM, also responded to our perception of the need to bring the subject of Physical Education closer to up-to-date teaching methods based on the concept of integral or holistic education.

Over the last two decades, new active methodologies have been appearing, trying to put the student at the centre of the teaching–learning process overcoming the traditional conception of Physical Education exclusively focused on physical possibilities and capacities. The new methods take into consideration students' individual necessities, and shifts focus from physical skills to health as a vital educational issue.

Before this study, SEM and TPSR had been applied in scientific research and there is bibliography in which SEM and TPSR prove effective in combination with the physical dimension of Physical Education to develop mental, social and emotional health. However, there are not so many studies which include those two models as a developmental tool of healthy habits as our research has done.

Considering the purpose of the research, the results of these study have concluded that the physical activity levels increased in the control group and experimental group, also there were significant improvements in standing long jump and speed-agility results in the control group. In the experimental group, on the contrary, no significant improvement was registered for either test, but out-of-school physical activity rates were higher.

TPSR and the amount of physical activity that students do in their leisure time.

Starting our research based on a syllabus design that was already in use at the school where the intervention took place proved positive for the development of our intervention since it already abided by Spanish educational legislation and did not interfere in the normal course of the subject of Physical Education. However, the shortcomings identified in our intervention, should be useful for upcoming studies to preclude the same difficulties.

Ideally, the intervention should be designed avoiding conditions dependant on external factors, such as the weather and other non-intrinsic restrictions. Moreover, the duration of the intervention should be longer as it has been argued in this research. Additionally, it would be useful to use a valid scale to assess physical fitness in order to quantify more precisely the extent to which results obtained in different moments have increased or decreased.

Investigations which defend a positive relation between physical activity levels and levels of satisfaction and motivation in the subject of Physical Education lessons were a starting point and determined the approach of this research. We conclude it now with the conviction that the whole educational system can play a role in the development of healthy active habits, so that physical activity and healthy habits pervade and transcend the context of formal education.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Ethics Committee of University of Murcia (ID: 4117/2022). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AQ-M: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. MC-I: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. BS-AM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. AG-M: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aparicio-Ugarriza, R., Mielgo-Ayuso, J., Ruiz, E., Ávila, J. M., Aranceta-Bartrina, J., Gil, Á., et al. (2020). Active commuting, physical activity, and sedentary behaviors in children and adolescents from Spain: findings from the ANIBES study. *Int. J. Environ. Res. Public Health* 17, 668–680. doi: 10.3390/ijerph17020668

Babu, T. A. (2022). Acute surge in the incidence of overweight and obesity in children – A spin-off epidemic triggered by the ongoing COVID-19 pandemic. *Curr. Med. Issues* 20, 120–121. doi: 10.4103/cmi.cmi_14_22

Bagherian, S., Nafian, S., and Baker, J. S. (2022). Is there a need to assess the health status of school-age students when reopening schools following the COVID-19 pandemic? *Epidemiol. Health Syst. J.* 9, 97–98. doi: 10.34172/ijer.2022.17

Bessa, C., Hastie, P., Araújo, R., and Mesquita, I. (2019). What do we know about the development of personal and social skills within the sport education model: a systematic review. *J. Sports Sci. Med.* 18, 812–829.

Blanco, M., Veiga, O. L., Sepúlveda, A. R., Izquierdo-Gómez, R., Román, F. J., López, S., et al. (2019). Family environment, physical activity and sedentarism in preadolescents with childhood obesity: ANOBAS case-control study. *Atención Primaria* 52, 250–257. doi: 10.1016/j.aprim.2018.05.013

Burgueño, R., Medina-Casaubón, J., Morales-Ortiz, E., Cueto-Martín, B., and Sánchez-Gallardo, I. (2017). Educación deportiva versus enseñanza tradicional: influencia sobre la regulación motivacional en alumnado de bachillerato. *Cuadernos de Psicología del Deporte* 17, 87–98.

Caballero-Blanco, P., Delgado-Noguera, M. A., and Escartí-Carbonell, A. (2013). Analysis of teaching personal and social responsibility model-based programmes applied in USA and Spain. *J. Human Sport Exer.* 8, 427–441. doi: 10.4100/jhse.2012.82.10

Calderón-Luquin, A., Hastie, P. A., and Martínez de Ojeda, D. M. (2010). Aprendiendo a enseñar mediante el modelo de educación deportiva (sport education model). Experiencia inicial en educación primaria. *Cultura Ciencia Deporte* 5, 169–180. doi: 10.12800/ccd.v5i15.103

Calderón-Luquín, A., Hastie, P. A., and Martínez de Ojeda, D. M. (2011). El modelo de educación deportiva. ¿Metodología de enseñanza del nuevo milenio? *Revista Española de Educación Física y Deportes* 395, 63–79. doi: 10.55166/reefd.v0i395.213

Carpena, P. J., Jiménez, M. I., Sánchez-Cubo, F., Ceballos-Santamaría, G., Vargas, M., and Mondéjar, J. (2023). Sociocultural differences in the development of obesity in adolescents in Murcia. *Endocrinología, diabetes y nutrición* 70, 352–359. doi: 10.1016/j.endien.2021.12.011

Carriedo, A., Fernández-Río, J., Méndez-Giménez, A., and Cecchini, J. A. (2022). Fitness testing: traditional model versus sport education model. *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte* 22, 269–284. doi: 10.15366/rimcafd2022.86.005

Casado-Robles, C., Mayorga-Vega, D., Guijarro-Romero, S., and Viciana, J. (2020). Is the sport education model effective in improving sportsmanship and physical activity in students? *Revista Internacional de Ciencias del Deporte* 16, 180–198. doi: 10.5232/ricyde

Castro-Piñero, J., Ortega, F. B., Artero, E. G., Girela-Rejón, M. J., Mora, J., Sjöström, M., et al. (2010). Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. *J. Strength Cond. Res.* 24, 1810–1817. doi: 10.1519/JSC.0b013e3181ddb03d

De Bont, J., Bennett, M., León-Muñoz, L. M., and Duarte-Salles, T. (2022). Prevalencia e incidencia de sobrepeso y obesidad en 2, 5 millones de niños y adolescentes en España. *Rev. Esp. Cardiol.* 75, 300–307. doi: 10.1016/j.recesp.2021.06.030

Decreto (2015). Decreto 220/2015, de 2 de septiembre de 2015, por el que se establece el currículo de la Educación Secundaria Obligatoria en la Comunidad Autónoma de la Región de Murcia. *Boletín Oficial de la Región de Murcia, 203, 3 de septiembre de 2015.*

Delgado-Floody, P., Carter-Thuillier, B., Guzmán-Guzmán, I. P., Latorrre-Román, P., and Camaño-Navarrete, F. (2020). Low indicators of personal and social development in Chilean schools are associated with unimproved academic performance: a national study. *Int. J. Educ. Res.* 104:101651. doi: 10.1016/j.ijer.2020.101651

Escartí, A., Gutiérrez, M., Pascual, C., and Llopis, R. (2010a). Implementation of the personal and social responsibility model to improve self-efficacy during physical education classes for primary school children. *Int. J. Psychol. Psychol. Ther.* 10, 387–402.

Escartí, A., Gutiérrez, M., Pascual, C., and Marín, D. (2010b). Application of Hellison's teaching personal and social responsibility model in physical education to improve self-efficacy for adolescents at risk of dropping-out of school. *Span. J. Psychol.* 13, 667–676. doi: 10.1017/S113874160000233X

Escartí, A., Gutiérrez, M., Pascual, C., and Wright, P. (2013). Observación de las estrategias que emplean los profesores de educación física para enseñar responsabilidad personal y social. *Revista de psicología del deporte* 22, 159–166.

Evangelio, C., Peiró, C., and González-Víllora, S. (2017). Hibridación como innovación: educación deportiva y educación física relacionada con la salud. *Tándem: Didáctica de la educación física* 57, 24–30.

Evangelio, C., Sierra-Díaz, J., González-Víllora, S., and Fernández-Río, J. (2018). The sport education model in elementary and secondary education: a systematic review. *Movimento* 24, 931–946. doi: 10.22456/1982-8918.81689

Farias, C., Valerio, C., and Mesquita, I. (2018). Sport education as a curriculum approach to student learning of invasion games: effects on game performance and game involvement. *J. Sports Sci. Med.* 17, 56–65.

Fernández-Hernández, A., Manzano-Sánchez, D., Jiménez-Parra, J. F., and Valero-Valenzuela, A. (2021). Analysis of differences according to gender in the level of physical activity, motivation, psychological needs and responsibility in Primary Education. *J. Hum. Sport Exerc.* 16, 580–589. doi: 10.14198/jhse.2021.16

Fernández-Rio, J., and Menéndez-Santurio, J. I. (2017). Teachers and students' perceptions of a hybrid sport education and teaching for personal and social responsibility learning unit. *J. Teach. Phys. Educ.* 36, 185–196. doi: 10.1123/jtpe.2016-0077

García-Castejón, G., Camerino, O., Castañer, M., Manzano-Sánchez, D., Jiménez-Parra, J. F., and Valero-Valenzuela, A. (2021). Implementation of a hybrid educational program between the model of personal and social responsibility (TPSR) and the teaching games for understanding (TGfU) in physical education and its effects on health: an approach based on mixed methods. *Children* 8:573. doi: 10.3390/children8070573

Gómez, S. F., Homs, C., Wärnberg, J., Medrano, M., González-Gross, M., Gusi, N., et al. (2020). Study protocol of a population-based cohort investigating physical activity, Sedentarism, lifestyles and obesity in Spanish youth: the PASOS study. *BMJ Open* 10:e036210. doi: 10.1136/bmjopen-2019-036210

Gómez-Buendía, A., Sánchez-Alcaraz, B. J., Cifo, M. I., and Gómez, A. (2022). Effects of a hybrid teaching model (SEM+ TGfU) and the model of personal and social responsibility on sportsmanship and enjoyment in 4 secondary and 1 baccalaureate students. *Retos: nuevas tendencias en educación física, deporte y recreación* 43, 550–559.

Gómez-Mármol, A., Sánchez-Alcaraz, B. J., De la Cruz, E., Valero, A., and González-Villora, S. (2017). Personal and social responsibility development through sport participation in youth scholars. *J. Phys. Educ. Sport* 17, 775–782. doi: 10.7752/jpes.2017.02118

Hastie, P. A., and Buchanan, A. M. (2000). Teaching responsibility through sport education: prospects of a coalition. *Res. Q. Exerc. Sport* 71, 25–35. doi: 10.1080/02701367.2000.10608877

Hellison, D. (2011). *Teaching personal and social responsibility through physical activity*. Human Kinetics, Champaign, IL

Hinojo Lucena, F. J., López Belmonte, J., Fuentes Cabrera, A., Trujillo Torres, J. M., and Pozo Sánchez, S. (2020). Academic effects of the use of flipped learning in physical education. *Int. J. Environ. Res. Public Health* 17, 276–290. doi: 10.3390/ijerph17010276

Hurtado-García, I., and Terrón-Bañuelos, A. (2022). Health education at the Spanish school (1970–1990): challenges at the intersection of fields of knowledge. *Historia y Memoria de la Educación.* 15, 99–135. doi: 10.5944/hme.15.2022.30589

Jiménez-Parra, J. F., Manzano-Sánchez, D., Camerino, O., Prat, Q., and Valero-Valenzuela, A. (2022). Effects of a hybrid program of active breaks and responsibility on the behaviour of primary students: a mixed methods study. *Behav. Sci.* 12, 90–113. doi: 10.3390/bs12050153

Kolimechkov, S. (2017). Physical fitness assessment in children and adolescents: a systematic review. *European Journal of Physical Education and Sport Science*. 3, 65–79. doi: 10.46827/ejpe.v0i0.653

Kurt, J., Hastie, P., Wadsworth, D., Foote, S., Brock, S., and Hollett, N. (2017). A sport education fitness season's impact on students' fitness levels, knowledge, and in-class physical activity. *Res. Q. Exerc. Sport* 88, 346–351. doi: 10.1080/02701367.2017.1321100

Ley Orgánica (2020). Ley Orgánica 3/2020, de 29 de diciembre, por la que se Modifica la Ley Orgánica 2/2006, de 3 de Mayo, de Educación (LOMLOE). *Boletín Oficial del Estado, 340, de 30 de diciembre de 2020*. Available at: https://www.boe.es/eli/es/lo/2020/12/29/3 (Accessed on 24 March 2023).

Ley Orgánica (2013). Ley Orgánica 8/2013, de 9 de diciembre, para la mejora de la calidad educative (LOMCE). Boletín Oficial del Estado, 295, de 10 de diciembre de 2013. Available at: https://www.boe.es/eli/es/lo/2013/12/09/8/con (Accessed on 24 March 2023).

Liu, N. Y. S., Plowman, S. A., and Looney, M. A. (1992). The reliability and validity of the 20-meter shuttle test in American students 12 to 15 years old. *Res. Q. Exerc. Sport* 63, 360–365. doi: 10.1080/02701367.1992.10608757

Lorente, E., and Joven, A. (2011). The impact of physical education based on autonomy and responsibility on student's everyday life: a longitudinal study. *Exer. Quality Life* 3, 1–18.

Lozano-Sánchez, A. M., Zurita-Ortega, F., Ubago-Jiménez, J. L., Puertas-Molero, P., Ramírez-Granizo, I., and Núñez-Quiroga, J. I. (2019). Videogames, physical activity practice, obesity, and sedentary habits in schoolchildren aged 10 to 12 years old in the province of Granada. RETOS. *Nuevas Tendencias en educación física, Deporte y recreación* 35, 42–46. doi: 10.47197/retos.v0i35.61865

Melero-Canas, D., Manzano-Sánchez, D., Navarro-Ardoy, D., Morales-Baños, V., and Valero-Valenzuela, A. (2021). The Seneb's enigma: impact of a hybrid personal and social responsibility and gamification model-based practice on motivation and healthy habits in physical education. *Int. J. Environ. Res. Public Health* 18:3476. doi: 10.3390/ijerph18073476

Menéndez, J. I., and Fernández-Rio, J. (2017). Hybridising sport education and teaching for personal and social responsibility to include students with disabilities. *Eur. J. Spec. Needs Educ.* 32, 508–524. doi: 10.1080/08856257.2016.1267943

Merino, R. G., and Mora, J. L. (2022). La hibridación de los modelos pedagógicos de aprendizaje cooperativo y educación aventura como estrategia didáctica para la mejora de la convivencia y la gestión de conflictos en el aula: una experiencia práctica desde las clases de educación física y tutoría. *Retos: nuevas tendencias en educación física, deporte y recreación* 43, 1037–1048. doi: 10.47197/retos.v45i0.91858

Opstoel, K., Chapelle, L., Prins, F. J., De Meester, A., Haerens, L., Van Tartwijk, J., et al. (2020). Personal and social development in physical education and sports: a review study. *Eur. Phys. Educ. Rev.* 26, 797–813. doi: 10.1177/1356336X19882054

Ortega, F. B., Ruiz, J. R., Castillo, M. J., Moreno, L. A., Urzanqui, A., González-Gross, M., et al. (2008). Health-related physical fitness according to chronological and biological age in adolescents. The AVENA study. *J. Sports Med. Phys. Fitness* 48, 371–379.

Pan, Y. H., Huang, C. H., Lee, I. S., and Hsu, W. T. (2019). Comparison of learning effects of merging TPSR respectively with sport education and traditional teaching model in high school physical education classes. *Sustainability* 11:2057. doi: 10.3390/su11072057

Pérez-Pueyo, Á., Hortigüela-Alcalá, D., Fernández-Fernández, J., Gutiérrez-García, C., and Rodríguez, L. S. (2021). Más horas sí, pero ¿cómo implantarlas sin perder el enfoque pedagógico de la Educación Física? *Retos* 39, 345–353. doi: 10.47197/retos.v0i39.80283

Perlman, D. J. (2010). Change in affect and needs satisfaction for amotivated students within the sport education model. *J. Teach. Phys. Educ.* 29, 433–445. doi: 10.1123/jtpe.29.4.433

Perlman, D. J. (2011). Examination of self-determination within the sport education model. *Asia-Pacific Int. J. Phys. Educ. Sports Health*, 2, 79–92. doi: 10.1080/18377122.2011.9730345

Perlman, D. (2012). The influence of the sport education model on amotivated students' in-class physical activity. *Eur. Phys. Educ. Rev.* 18, 335–345. doi: 10.1177/1356336X12450795

Pritchard, T., Hansen, A., Scarboro, S., and Melnic, I. (2015). Effectiveness of the sport education fitness model on fitness levels, knowledge, and physical activity. *Physical Educator* 72, 577–600.

Prochaska, J. J., Sallis, J. F., Slymen, D. J., and McKenzie, T. L. (2003). A longitudinal study of children's enjoyment of physical education. *Pediatr. Exerc. Sci.* 15, 170–178. doi: 10.1123/pes.15.2.170

Ramos-Pino, J. M., and Carballeira, M. (2022). Conocimientos, creencias y actitudes sobre la obesidad y el sobrepeso en una muestra de dietistas-nutricionistas de España. *Nutr. Hosp.* 39, 63–72. doi: 10.20960/nh.03739

Rodríguez, J. E., Rico-Díaz, J., Neira-Martín, P. J., and Navarro-Patón, R. (2021). Actividad física realizada por escolares españoles según edad y género. *Retos: nuevas tendencias en educación física, deporte y recreación* 39, 238–245. doi: 10.47197/retos.v0i39.77252

Rosa, A., García, E., and Carrillo, P. J. (2019). Physical activity, physical fitness and self-concept in schoolchildren aged between 8 to 12 years old. *Retos* 35, 236–241. doi: 10.47197/retos.v0i35.64083

Salas-Sánchez, M., and Vidal-Conti, J. (2020). Orientaciones para crear patios activos en los centros escolares. Retos: nuevas tendencias en educación física. *Deporte y recreación* 38, 745–753. doi: 10.47197/retos.v38i38.73038

Saliba, K., and Cuschieri, S. (2021). Amidst the COVID-19 pandemic childhood obesity is still an epidemic-spotlight on obesity's multifactorial determinants. *Health Sci. Rev.* 1:100006. doi: 10.1016/j.hsr.2021.100006

Sánchez-Alcaraz, B. J., Cañadas, M., Valero, A., Gómez, A., and Funes, A. (2019). Resultados, dificultades y mejoras del modelo de responsabilidad personal y social. *Apunts. Educación Física y Deportes* 35, 62–82. doi: 10.5672/apunts.2014-0983.es.(2019/2).136.05

Sánchez-Alcaraz, B. J., Courel, J., Sánchez, C., Valero, A., and Gómez, A. (2020). Personal and social responsibility model through sports: a bibliographic review. *RETOS – Neuvas Tendencias en Educacion Fisica, Deporte y Recreacion* 37, 755–762.

Sánchez-Alcaraz, B. J., Gómez-Mármol, A., Valero, A., De la Cruz, E., and Díaz, A. (2016). El Modelo de Responsabilidad Personal y Social a través del deporte como propuesta metodológica para la educación en valores en adolescentes. *Espiral. Cuaderno del Profesorado* 9, 16–26. doi: 10.47197/retos.v37i37.67890

Sánchez-Alcaraz, B. J., Ros, E., Alfonso-Asencio, M., Hellín, M., and Gómez-Mármol, A. (2021). Personal and social responsibility and physical activity participation in students. E-balonmano.Com. *J. Sport Sci.* 17, 171–180.

Segovia, Y., and Gutiérrez, D. (2020). Esfuerzo, implicación y condición física percibida en un programa HIIT en educación física. modelo educación deportiva vs metodología tradicional. *Retos* 38, 151–158.

Seners, P. (2001). *La lección en Educación Física*. INDE, Barcelona.

Siedentop, D., Hastie, P. A., and Mars, H. (2004). *Complete guide to sport education*. Human Kinetics, Champaign, IL.

Spittle, M., and Byrne, K. (2009). The influence of sport education on student motivation in physical education. *Phys. Educ. Sport Pedagog.* 14, 253–266. doi: 10.1080/17408980801995239

Thomas, J. R., Nelson, J. K., and Silverman, S. J. (2011). *Research methods in physical activity*. Human Kinetics, Champaign, IL.

Valero-Valenzuela, A., Camerino, O., Manzano-Sánchez, D., Prat, Q., and Castañer, M. (2020a). Enhancing learner motivation and classroom social climate: a mixed methods approach. *Int. J. Environ. Res. Public Health* 17:155272. doi: 10.3390/ijerph17155272

Valero-Valenzuela, A., Gregorio García, D., Camerino, O., and Manzano, D. (2020b). Hybridisation of the teaching personal and social responsibility model and gamification in physical education. *Apunts. Educación Física y Deportes* 141, 63–74. doi: 10.5672/apunts.2014-0983.es.(2020/3).141.08

Wallhead, T. L., Garn, A. C., and Vidoni, C. (2014). Effect of a sport education program on motivation for physical education and leisure-time physical activity. *Res. Q. Exerc. Sport* 85, 478–487. doi: 10.1080/02701367.2014.961051

Wärnberg, J., Pérez-Farinós, N., Benavente-Marín, J. C., Gómez, S. F., Labayen, I. G., Zapico, A., et al. (2021). Screen time and parents' education level are associated with poor adherence to the Mediterranean diet in Spanish Children & Adolescents: the PASOS study. *J. Clin. Med.* 10, 795–810. doi: 10.3390/jcm10040795

World Health Organization (2020). *Guidelines on physical activity and sedentary behaviour: At a glance*. World Health Organization: Geneva, Switzerland.

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Teaching STEAM in the shaolin staff program: ways to stimulate student engagement in learning

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With the advancement of technology and change in education concepts, applying STEAM pedagogy to physical education has become an innovative trend. This study investigates whether physics analysis based on STEAM concepts can increase junior high students' participation in learning Shaolin Staff. Forty students were randomly assigned to experimental and control groups. The mean and standard deviation of age in the experimental group was 13.95 ± 0.83, and in the control group was 13.85 ± 0.81. The experimental group received STEAM teaching involving physics analysis, while the control group received conventional movement instruction. Student learning engagement was evaluated through questionnaires. Results are expected to show the experimental group being more engaged in learning. Introducing physics analysis may deepen understanding of related principles to movements. The study's results found that the scores of motivation, attention, and intention to learn independently were significantly higher in the experimental group than in the control group ($p < 0.01$). The scores of interfering emotions were significantly lower in the experimental group than in the control group ($p < 0.01$), which verified that the STEAM teaching method could effectively improve learning engagement. This study promotes STEAM education in martial arts and provides insights on utilizing STEAM to boost student engagement.

KEYWORDS

STEAM teaching concepts, shaolin staff, learning engagement, physics analysis, video analysis

Introduction

STEAM education emphasizes the organic integration of science, technology, engineering, art, and other disciplines to provide a cross-disciplinary learning approach. This teaching method can stimulate students' intrinsic motivation and enthusiasm for learning through a variety of ways, and STEAM education focuses on hands-on and inquiry-based project learning, allowing students to change from passive acceptance of knowledge to active participation in the process, giving full play to the subjectivity of learning (Wu, 2023). Research has shown that STEAM focuses on students' creativity and imagination, encourages innovative practices, and allows trial and error. Project-making and art activities make learning fun. Furthermore, STEAM education provides a contextualized and immersive learning environment, applying knowledge to life situations and stimulating students' emotional experience and engagement. In addition, the timely feedback mode of STEAM can bring a successful experience, satisfy students' sense of achievement, and motivate them to continue learning (Belbase et al., 2022).

It can be seen that the student-centered, participatory, and innovative learning elements of STEAM education can effectively stimulate motivation and enhance engagement in learning. This interdisciplinary approach teaches students about sustainable development while enhancing their understanding of related environmental issues and their ability to develop solutions. The interweaving of STEAM subjects with sustainability equips students with the knowledge and skills to comprehend and tackle the complex challenges of creating a just and ecologically sound future (Malecha, 2020).

STEAM education has gained traction recently, with increasing numbers of schools and teachers adopting this approach. As STEAM education proliferates, research into its implementation and impacts has grown. Song Naiqing et al. propose that assessment systems aligned with STEAM education principles could stimulate students' intrinsic learning motivation. Integrating STEAM across curricula may cultivate key skills, including cognition, cooperation, innovation, and professional abilities. Well-designed assessments would allow students to identify their knowledge gaps, take initiative in their learning, and thus build endogenous motivation. This motivational force could potentiate the development of the diverse competencies needed to equip students for the future. Further research should investigate optimal assessment strategies to unlock the motivational and skills-development potential of STEAM education (Naiqing and Xin, 2021). Zhu Liming et al. propose that deep learning approaches inspired by the interdisciplinary framework of STEAM education could inform advances in core literacy, integrated curricula, and pedagogical innovations. Unlike technology-centric perspectives, STEAM-based deep learning promotes a humanistic style, prioritizing students' emotional experiences and engagement during learning. Well-controlled studies are critical to elucidate the relative merits of humanistic, STEAM-based deep learning versus technology-focused methods. Such insights could refine emerging practices that effectively integrate STEAM and humanistic values, helping prepare students to navigate a complex world (Zhu Liming et al., 2023). Wenchao et al. propose integrating traditional cultural heritage within the interdisciplinary STEAM education framework. They argue that this synergy could enable the enduring transmission of cultural knowledge while advancing educational goals. The "interdisciplinary" ethos of STEAM could allow the holistic incorporation of traditional culture, infusing social responsibility, morality, and Chinese values. This may mitigate the utilitarian reputation of STEAM fields and foster deeper integration with the humanities. Further, student interest is critical for sustaining STEAM education (Wenchao et al., 2022). STEAM education for sustainable development takes this further by incorporating sustainability principles. This interdisciplinary approach teaches students about sustainable development while enhancing their understanding of related environmental issues and their ability to develop solutions (Hsiao and Su, 2021). For example, by integrating concepts of science, technology, and engineering with environmental ethics and nature conservation, students can gain holistic perspectives and skills to analyze complex sustainability challenges and develop innovative solutions (Yarime et al., 2012).

Yang et al. developed an elementary curriculum integrating STEAM and manufacturing concepts to foster interdisciplinary skills. This unified framework nurtures creativity, problem-solving, and student interest in STEAM fields. The authors highlight that stimulating self-efficacy through early manufacturing-STEM education may engage students and provide scaffolding to tackle complex real-world problems (Jia et al., 2021). Hsiao et al. explored the intersection of sustainability, STEAM education, and Virtual Reality (VR) technology in an experiential learning course. The study noted that combining STEAM with sustainability and VR technology to design an experiential learning course increased student motivation, satisfaction, and learning outcomes (Hsiao and Su, 2021).

Physical education is an important part of education. Integrating STEAM education concepts into physical education teaching can not only enable students to master sports skills and physical health knowledge but also cultivate comprehensive qualities such as scientific thinking, innovation, problem-solving ability, and teamwork so that they can have a more comprehensive development in physical education. While stimulating students' interest in learning physical education courses, it opens students' minds and further enhances teachers' teaching effect. Integrating STEAM education concepts into physical education is an emerging teaching model that is gradually emerging at home and abroad, and there are more and more research results related to it. Lee examined the effects of STEAM-based physical education classes on students' self-directed learning abilities and attitudes toward physical education classes related to alienation and avoidance of physical education through an experimental control method. The study showed that a physical education program incorporating STEAM education concepts positively impacted students' attitudes and self-directed learning abilities in physical education classes, and he suggested integrating STEAM education with physical education (Lee, 2020). He also emphasized the need to apply dynamic pedagogical approaches and STEAM programs in physical education to address issues related to teacher instruction, student alienation, and avoidance of physical education (Lee, 2021). Yuan et al. explored the effects of continuous exercise on the positive psychological emotions of elementary school students by integrating STEAM education concepts under physical exercise. The current situation of physical exercise and the overall situation of positive psychological emotions of elementary school students were analyzed, and the role of physical exercise on positive psychological emotions of elementary school students was studied. Regular physical exercise can improve students' physical and mental qualities and is essential for their comprehensive development (Yuan et al., 2022). The study of Iyakrus et al. concluded that the physical education teaching model established based on the STEAM education concept could effectively improve the physical fitness of elementary school students (Ramadhan, 2021).

It is clear from the above research that the STEAM education concept has emerged globally and is widely used in the current education sector. The concept combines science, technology, engineering, art, and math. It can cultivate students' innovative and interdisciplinary thinking, stimulate their motivation and interest in learning, help them understand and apply knowledge more comprehensively, and cultivate comprehensive thinking and problem-solving skills. Incorporating STEAM education concepts into physical education teaching not only enables students to master motor skills and physical health knowledge but also improves their comprehensive qualities such as scientific thinking, innovation, problem-solving ability, and teamwork. So that they have a more comprehensive development in the field of sports. Domestic scholars have conducted fewer studies on integrating STEAM education concepts with physical education and even fewer studies on integrating traditional sports programs. Therefore, this study combines STEAM education concepts with the teaching curriculum of Shaolin Staff, a traditional Chinese sports program, to explore STEAM education concepts' effects on students' engagement in learning Shaolin Staff.

Many scholars in the above literature have explored the effects of integrating STEAM education concepts into teaching and learning on students' independent learning ability, attitudes toward physical education programs, and mental–emotional and physical fitness through experimental design methods. Few studies combine STEAM education concepts with traditional Chinese sports programs, so the experimental designs and other research methods used in the above scholars' studies can provide precedents and theoretical foundations for the design and conduct of the experiments in this paper.

Learning engagement refers to the degree to which students participate in the learning process's physical, cognitive, and social dimensions. High levels of learning engagement increase student academic achievement, degree completion, and the creation of meaningful learning experiences. Learner engagement is an important instructional consideration in teacher education (Seo and Gibbons, 2019). This study focuses on five key dimensions of learning engagement: motivation, attention, intention to learn independently, satisfaction, and disturbing emotions. Motivation refers to students' desire to participate in learning activities. Attention represents the focus and concentration on learning tasks. Intention to learn independently reflects students' self-driven efforts to comprehend knowledge. Satisfaction indicates the fulfillment and pleasure gained through learning. Disturbing emotions refer to negative affective states like anxiety, boredom, and frustration during learning (Sun, 2022). Self-efficacy and self-directed learning abilities are closely related to learning engagement. Both self-efficacy and self-directed learning abilities foster a sense of ownership and empowerment in students' learning experiences. When students believe in their capabilities and have the skills to guide their learning, they are more likely to become motivated, proactive learners who are fully engaged in their educational pursuits (Schunk and Zimmerman, 1994).

Personalized learning emphasizes that the learning process should begin with the learner and that participation should drive decision-making. Implementing and assessing personalized learning environments give learners more voice, promoting engagement and better learning outcomes. Thus, learning engagement can be used to view the learner experience, which enriches the understanding of the language of learner performance, skills, and competencies. Understanding the complexity and multidisciplinarity of learner engagement can be achieved by exploring the development of personalized learning environments and applying ideas from social media (Ballard, 2013). Learner engagement is strongly associated with important educational outcomes such as academic achievement and satisfaction. While some research has been conducted on learner engagement in blended learning environments, there is a lack of consistency and specificity in the definition, operationalization, and measurement of engagement. Therefore, developing a framework for defining, modeling, and measuring factors of learner engagement is critical to determining whether changes in instructional methods increase engagement. The study reviews existing literature on learner engagement and identifies constructs relevant to blended learning. The study proposes a possible conceptual framework for engagement, including cognitive and affective metrics, and provides methods for measuring these metrics in a technology-mediated learning environment (Halverson and Graham, 2019). The importance of engagement in learning has received much attention in education. Student engagement is closely related to educational outcomes, such as academic achievement, learning satisfaction, and school retention. Research has shown that creating interactive, personalized learning environments promotes student engagement. Teachers play a key role in the teaching and learning process, and they should use various teaching strategies to encourage active student participation and provide support and feedback. In addition, schools and education policymakers should also pay attention to learning engagement and provide resources and support to improve the learning environment to stimulate students' motivation and interest in learning (Carini et al., 2006). Overall, learning engagement significantly impacts student achievement and learning experiences.

The staff, the most representative long weapon of Chinese martial arts, has much room for development. For thousands of years, it has been the most adaptable of Chinese martial arts instruments (Liu, 2014). An ancient martial arts proverb says, "The staff is the leader of all martial arts (Tang, 2008)." It is in this sense that it is said. On the other hand, the staff is also the most representative and central instrument of Shaolin Kungfu. The staff has played an important historical and cultural role in different Shaolin Kung Fu development periods. The unique guardian of the Shaolin Temple, King Jinnaluo, was famous for using the staff, and the historical legend of "Thirteen Monks with Staffs Saving Tang "also centered on using the staff by monks and soldiers. In the Ming Dynasty (1,386–1,644), when the development of Shaolin martial arts was in a subversive stage, the Shaolin staff became the most representative element of Shaolin Kung Fu in the world of martial arts (Shahar, 2001). At that time, Shaolin monks and soldiers were ordered to be recruited to the southeast coast to fight against the Japanese and protect the country. One of the basic techniques used was the Shaolin Staff Technique. Yuanyi, in his great book on military science, Wu Bei Zhi, has a paragraph stating that "all martial arts are based on the staff, and the staff is based on Shaolin" (Mao, 1984).

The inheritance and innovation of Shaolin Staff teaching methods are crucial to promoting the modernization and social value of this traditional martial art. Integrating STEAM concepts can achieve this goal by making learning more engaging and interdisciplinary. Student participation is vital for engagement in the STEAM teaching process. Therefore, this study assesses students' interdisciplinary knowledge and learning engagement to reflect the quality of STEAM-integrated Shaolin Staff instruction. Analyzing physics principles cultivates systemic thinking to comprehend complex issues like sustainability. Assessing learning engagement provides key insights into the effectiveness of applying STEAM to modernize Shaolin Staff teaching while making it relatable to students' development needs. This underscores the importance of participatory STEAM instruction for inheriting and innovating traditional martial arts education.

This study is framed by the theory of learning engagement (Halverson and Graham, 2019), which emphasizes active participation and student-centered learning. The degree of engagement is associated with academic outcomes. The implementation of STEAM education is grounded in constructionist learning theories (Morado et al., 2021), which posit that learning occurs most effectively when students construct their understanding through designing and creating things. Video analysis technology draws on personalized learning theories (Peng et al., 2019), highlighting customized feedback to meet individual learner needs. These theories jointly informed the instructional design and analysis of results.

We are developing a series of traditional martial arts programs integrating STEAM to achieve this goal. The aim is to fully develop students' knowledge, abilities, and literacy at the K-12 level. This paper reports the results of our first round of development and answers the following questions: (a) How to integrate STEAM concepts into the curriculum framework based on STEAM teaching and learning? (b) How do we develop a curriculum based on the framework? (c) How to assess the effectiveness of the developed curriculum? We expect to improve the Shaolin Staff curriculum's learning experience and outcomes by focusing on student engagement in learning.

Research objects and methods

Objects of study

A non-random sampling method was used in this study. The following requirements were met: the study subjects had to be in the second year of junior secondary school. This means they should be in the second academic year of the secondary education system, usually between the ages of 13 and 14. The study population consisted of both boys and girls. It has been shown that a small class size is more suitable for blended learning programs like STEAM because it is more conducive to teacher-student interaction. In small class teaching in China, a class usually has no more than 25 students (Jyun, 2021).

Research methods

Experimental method

The experimental group was taught martial arts by introducing the STEAM teaching concept, and the control group was taught traditional martial arts. The teaching process was divided into three main parts, i.e., the preparation part (5 min), the basic part (35 min), and the ending part (5 min), and the same teacher led the practice for a total of 14 lessons. In the pre-experimental period, the POLAR TEAM2 table and the K4B2 cardiopulmonary function tester were applied to test the exercise intensity of the Shaolin Staff Technique. It was made to reach the medium intensity level and medium intensity aerobic exercise. The athlete's respiratory heart rate increased significantly, and the heart rate reached (170-age) ± 10–20 beats. At this time, the subjective feeling is that the respiration and heartbeat are accelerated, slightly sweating, and can speak but not sing (Shanxi Sports Science Institute, 2021). The moderate intensity in this experiment was controlled at (Max HR) 60–70%. The heart rate was monitored in real time for experimental and control groups. Wearing a heart rate monitor controlled their heart rate at a moderate intensity level. The exercise intensity can be controlled in the experiment by adjusting the time between exercises and intervals, the center of gravity, and the height of movements during exercises so that the subjects sweat slightly without feeling fatigued. Parents or guardians of all the participants in this study signed an informed consent form to ensure that the study complied with ethical norms. There were ten boys and ten girls in each group of this experiment. There were 20 cases in the experimental group and 20 in the control group. Consent to participate in this study should be obtained from the study subjects. Patients with contraindications to exercise were excluded. Subjects who were unwell on their way to the experiment and those who needed better compliance and did not comply with the experiment were excluded. Figure 1 shows the design flow of this experiment.

Framework for developing an integrated STEAM program

Course overview and goals

Introduce the background and goals of the course, emphasizing the importance of STEAM teaching concepts in increasing student engagement in learning. Articulate the goals of the course, including increasing student interest, motivation, and engagement in the Shaolin Staff program, as well as fostering their scientific literacy and skill development.

Science module

Introduces the principles of human kinematics and mechanics and explores their relevance to staff movements. Analyze the effects of staff fighting on the body and study energy transformation and force. Explore the relationship between staff skills, anatomy, physiology, and motor control. Conduct hands-on activities that allow students to apply scientific principles to optimize staff handling movements.

Technology module

Quantitatively analyzing and improving staff movements using video analysis software. Record and analyze individual staff-fighting demonstrations using video capture and editing techniques. Use mobile apps and online resources to access information about martial arts history and techniques.

Art module

Appreciate ancient Shaolin staff fighting songs and drawings and create routines that express Shaolin culture and philosophy to demonstrate the beauty of staff fighting. Students are encouraged to learn traditional Shaolin staff fighting performances and movement choreography to demonstrate grace and fluidity of movement.

Mathematics module

Analyze the angles and strength of staff movements involving concepts of geometry and trigonometry. Calculate the speed and acceleration of staff movements using kinematics and dynamics formulas.

Assessment and feedback approach

Utilize an array of effective assessment methods, encompassing practical performance evaluations, interviews, and questionnaires. The Learning Engagement Scale was employed to comprehensively evaluate students' engagement, including motivation, attention, intention to learn independently, satisfaction, and disturbing emotions (Sun, 2022). The scale's internal consistency reliability (Cronbach's alpha) was established at 0.81, ensuring measurement accuracy. Employ questionnaires to gather data on students' learning engagement and gage their level of involvement and interest in the course. Implement a consistent cycle of instructional feedback from educators and students to continually enhance and refine course content and instructional techniques.

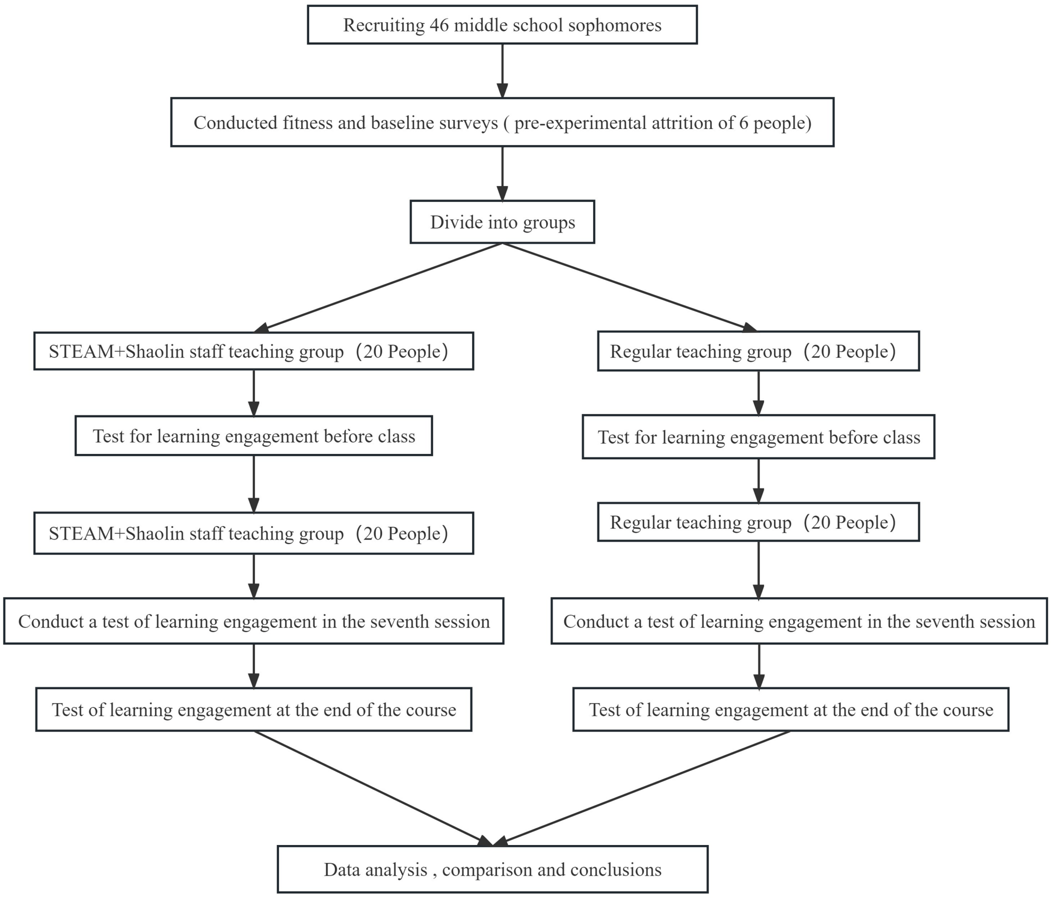

FIGURE 1
Flow chart of instructional design.

Integration of STEAM framework and interview insights

Our developmental framework integrates STEAM teaching principles by fusing science, technology, art, and math into the Shaolin Staff curriculum. This strategic integration elevates student learning engagement by applying physics analysis and video analytics. After the experiment, we conducted semi-structured interviews with 20 participants randomly selected from the STEAM teaching group. The primary aim was to gather qualitative insights into their learning journey and perceptions of the STEAM-incorporated Shaolin Staff course. The interview format encompassed open-ended questions strategically designed to uncover students' perspectives regarding the amalgamation of science, technology, art, and math within the curriculum and the potential impact on their learning engagement.

Course design of Shaolin staff technique

The course covers several principles of physics:

1. Rotational Moment: The rotational moment is the force acting on an object that causes the object to rotate around a fixed axis. Its magnitude is equal to the product of the force and the force arm, which is the perpendicular distance between the force and the axis of rotation. The rotational moment determines the speed and direction of rotation of the object.
2. Moment of Inertia: The moment of inertia is the property of an object that resists changing its rotation state. It is related to the object's mass distribution and its axis's position. The larger the moment of inertia, the more difficult it is for the object to change its rotation state. The moment of inertia can be used to describe the response of an object to a rotational moment.
3. Angular Velocity: Angular velocity is the rate of change of angle per unit of time when an object is rotating about an axis. It indicates the speed of rotation and is expressed in radians per second. The greater the angular velocity, the faster the object rotates.
4. Linear Velocity: Linear velocity is the speed of a point on an object along a trajectory as it rotates. It is related to the angular velocity and the distance from the axis of rotation to that point. Linear velocity is a physical quantity that describes the difference in velocity at different points on a rotating object.
5. Balance Lever: A balance lever is a rigid rod supported by a fulcrum with forces of different magnitudes or directions acting on either side. The principle of a balanced lever is based on the law of levers, which states that the left side moment equals the right side moment, making the lever balanced. This means that a balanced lever will remain at rest when the force

on the left multiplied by its distance to the fulcrum is equal to the force on the right multiplied by its distance to the fulcrum.

6. Interaction Force: Interaction force is the force exerted by two objects on each other. According to Newton's third law, interaction forces always occur in pairs and are equal in magnitude and opposite direction. When one object exerts a force on another object, the other object also exerts a force of equal magnitude and opposite direction on the first object. These forces are the result of the interaction between two objects (see Table 1).

In addition, the content we selected for teaching Shaolin Staff originated from the book "Explanation of Shaolin Staff Technique" by Cheng Zongyou, a famous martial arts master in the Ming Dynasty. In order to realize the characteristics of Arts in the STEAM teaching concept, we also set the contents of the drawings and staff tips in the staff score in the teaching of the corresponding technical movements, respectively. This enables students to understand the historical origins of the Shaolin Staff Technique and improves their ability to recognize and discover beauty (as shown in Figures 2, 3).

Teaching cases

Description of the Xiapi (下劈)

The left foot slightly stirs the ground, and the left waist, hips, and shoulders are quickly twisted to the right so that the front of the body faces the front. The left-hand raises the staff forward and upward to a position at the same height as the forehead. At the same time, the right hand quickly slides down the staff so that the right hand is directly above the head. The waist and hips are then quickly twisted to the left, and the right-hand slide handle is pressed downward. The left hand pulls down and presses down so the staff splits horizontally. The arms are then pushed upward to inhibit the downward movement of the staff.

This movement can be analyzed in three stages:

1. Initial state: the right foot is in front, and the left is behind in a slight stirrup. The front of the body is slightly to the left, arms down, holding the staff.
2. Stage 1: the left side of the waist, hips, and shoulders are twisted to the right, utilizing the legs and lower back muscles to exert force and give themselves a rotational torque. This torque can be described by Newton's law, acting on the center of mass of the body with the magnitude:

$$M = J * a \tag{1}$$

M is torque, J is the moment of inertia, and a is the angular acceleration. The moment of inertia is a physical quantity that describes the ease with which an object can rotate, and it can be calculated using the following equation:

$$J = m * r^2 \tag{2}$$

Where m is the object's mass and r is the distance from the axis of rotation to the center of mass.

At the same time, the left-hand raises the staff forward and upward to a position at the same height as the forehead. The right hand quickly slides down the staff to position the right hand directly above the head. During this process, the left arm will be lifted faster than the right arm slides down, and the force arm becomes longer; the body's rotational inertia is also changing.

During this process, the lower limb muscles must be controlled to support the body weight and maintain balance. At the same time, the involvement of muscles such as the low back musculature and the rectus abdomens plays a key role in the steering of the body. The lifting motion of the left arm is achieved through the strength of the scapular girdle and upper arm muscles. The sliding of the right hand, on the other hand, requires the corresponding joints of the shoulder, elbow, and wrist to work in tandem to control the accuracy and speed of the movement.

3. Stage 2: the waist and hips are quickly twisted to the left, the right-hand slide handle is pressed forward and downward, and the left hand is pulled downward and pressed so the staff splits downward when it reaches a horizontal position. The velocity of the endpoint of the staff changes from $\overrightarrow{v_1}$ to $\overrightarrow{v_2}$ with the velocity formula:

$$\overrightarrow{v_1} = \overrightarrow{\omega_1} \times \overrightarrow{R_1} \tag{3}$$

$$\overrightarrow{v_2} = \overrightarrow{\omega_2} \times \overrightarrow{R_2} \tag{4}$$

Where $\overrightarrow{\omega_1}$ and $\overrightarrow{\omega_2}$ are the angular velocity before and after action, $\overrightarrow{R_1}$ and $\overrightarrow{R_2}$ are the radius before and after action, respectively.

This process involves muscle contraction and relaxation to maintain balance in the body's tilting and the staff's movement. At the same time, the sliding speed of the staff must be allowed to accelerate at an even rate to increase the force on the target.

4. Stage 3: the arms are powered upward to inhibit the continued downward movement of the staff. The main function of this phase is to counteract the effect of gravity on the staff and ensure that the staff does not continue to fall downward after the downward chop has reached the designated position. In this process, a reverse force equal to the gravity of the staff needs to be applied, which can be calculated using the following formula:

$$\left|\overrightarrow{F_1} + \overrightarrow{F_2}\right| = m_{器械} * g \tag{5}$$

This process requires a synergy of muscles throughout the body to stabilize the balance of the body and control the staff through the resistance of the arms and force generation of the legs.

The main mechanical concepts involved in the downward chop are rotational moment, balanced leverage principle, interaction force, muscle control, etc. Strong muscle strength and body control are required to maintain good balance and arm accuracy. At the same time, one needs to master the coordinated movement of the scapular girdle and upper arm muscles to achieve smooth and powerful movements (Figures 4–7).

TABLE 1 Course design of Shaolin Staff technique.

Subject	Action	Content	Lesson	Physical principles
Fighting position	Zhongsiping position (中四平势)	Stand upright, holding the staff in the right hand to keep it straight. Turn to the left side with the right foot as the axis, and at the same time, step back with the left foot, forming a Gongma stance, with the distance between the feet slightly greater than the shoulder and the center of gravity of the body falling between the two feet. The toes of the right foot are slightly inwardly buckled toward the front, the toes of the left foot are toward the right front, and the heel is lifted; the horizontal distance between the front and back feet is about half a foot; at the same time, the left-hand slides downwards along the staff, and grips it to the end of the staff, the right-hand grips the staff and presses it forward and downwards, with the two arms slightly curved, and the distance between the hands is somewhat wider than that of the two feet; the upper body stays straight, the chest and the stomach are contained, the two shoulders are sunk to the lower part of the body, and the front end of the staff is slightly lifted, with the eyes looking at the front.	1	Balance stability, the center of gravity adjustment
footwork	Xiaogongbu (小弓步)	Turn hips with the left foot in the stirrups so that the front of the knee is perpendicular to the ground and the front of the body is facing forward.	1	Interaction forces, the center of gravity adjustment
	Gongbu (弓步)	Stomp the ground with the back foot and take a big step forward with the front foot while bending at the knee, with the thigh nearly horizontal and the knee perpendicular to the toes.	1	
	Tibu (提步)	The right foot stirs the ground, the center of gravity shifts back to the left leg, the right foot is quickly lifted to the rear, and the left leg is assisted to stir straight. Currently, the left leg independently supports the body, the right leg is lifted backward in the air, the center of gravity is transferred from the left leg to the waist and abdomen, and the body is tilted forward.	1	
Offensive technique: Zha	Pinzha (平扎)	The left foot stirrups and turns to the right, quickly driving the left side of the waist and hips to the right so that the body is facing forward; the left shoulder is sent on at the same time as the left arm holding the soldier ahead stabbing, the right arm is quickly raised to assist in the forward delivery of the right-hand does not move to ensure that the staff from the right-hand slides through smoothly.	1	Rotational torque, moment of inertia, linear velocity
	Shangzha (上扎)	Twist the left foot to the right, quickly drive the left side of the waist and hips to the right so that the body is facing forward, the left shoulder to the front at the same time as the left arm forward and upward stabbing, the right arm quickly raised to assist the forward and upward, the right-hand does not move, to ensure that staff from the right-hand slides through smoothly.	1	
	Xiazha (下扎)	The left foot stirrup is twisted to the right, quickly driving the left side of the waist and hips twisted to the right so that the body is facing forward; the left shoulder is sent forward at the same time that the left arm is stabbed forward and downward, the right arm is quickly raised to assist the forward and downward, the right-hand does not move to ensure that the staff from the right-hand slides through smoothly.	1	
	single-handed zha (单手扎)	The left foot stomps the ground to twist to the right, quickly driving the left side waist and hips to twist to the right; the left shoulder is sent out to the front to the maximum extent at the same time the left arm jabs out to the front, at the same time the right hand detaches from the staff and quickly extends out to the back to assist the body to twist to the right.	1	
Offensive Technique: Li	Xia Pi (下劈)	The left foot slightly stirrups the ground, the left side of the waist and hips and shoulders quickly twisted to the right so that the front of the body facing the front, the left hand forward and upward lifting equipment, and the forehead at the same height position, at the same time, the right hand quickly along the equipment downward slide, so that the right hand is located in the head is directly above. Then the waist and hips quickly to the left twisted, the right hand sliding the handle forward to the downward pressure, the left hand is also downward pulling and pressure, so that the equipment downward cleaves to the horizontal position, arms upward force to inhibit the continuation of downward movement of the equipment.	1	Rotational torque, moment of inertia, angular velocity, linear velocity

(Continued)

TABLE 1 (Continued)

Subject	Action	Content	Lesson	Physical principles
Advanced Offensive Techniques	Immortal sits in a cave posture (仙人坐洞势)	The center of gravity is shifted back to the left leg, the body sits back, the end of the staff is pressed against the left side of the waist and abdomen, the staff is pointed toward the opponent, and then one hand is zipped out violently.	1	Balance stability, the center of gravity adjustment
	Jiashan posture (夹衫势)	The right hand violently sends the staff backward. Both hands simultaneously slide forward to grasp at the front half of the staff; the left arm holds the staff under the armpit, the right hand will nearly grasp at the front end of the staff, and the left foot steps forward upward and quickly approaches.	1	
Defensive techniques	Upper right block (右上路格挡)	The body is turned slightly to the right; the right arm is bent at the elbow, the right hand slides slightly under the handle and recovers toward the right front of the chest, and the left hand is then pushed slightly forward and downwards so that the upper part of the staff protects the head.	1	leveraging
	Left center block (左中路格挡)	The body is turned to the left; the right arm is bent at the elbow; the right hand slides the handle slightly upwards and recovers toward the left front of the head, and the left-hand moves forward to be in a perpendicular position to the right hand so that the staff is guarded on the left side of the torso.	1	
	top-shelf block (上架)	Turn right with left foot on the ground, turn body naturally to the front, and raise both arms forward and upward simultaneously so the staff is laterally parallel to the ground and high above the head.	1	

Findings of the study

Students' engagement in learning

The five dimensions of learning engagement examined were motivation, attention, intention to learn independently, satisfaction, and disturbing emotions. The learning engagement scores collected from the questionnaire survey were compared and analyzed between the two groups before and after the experiment. The chi-square test was used for count data. The count data were calculated to be consistent with normal distribution, which repeated measures and group simple effects tests can test. As shown in Table 2, there is an interaction effect between different interventions and intervention time in the dimensions of motivation, attention, intention to learn independently, satisfaction, and disturbing emotions.

Regarding the learning motivation dimension, it was found by multiple comparisons that the mean values of the learning motivation dimension of the pre-test, the mid-test, and the post-test of the learning motivation dimension increased in the order of significance ($p < 0.01$) in the group where the STEAM teaching concept was introduced. In the group using conventional teaching, the mean value of the learning motivation dimension of the pre-test was significantly higher than that of the post-test ($p < 0.01$). However, it was not significantly different from the mid-test ($p = 0.093$). The group simple effects analysis results showed that in the baseline, there was no significant difference in the mean values of the learning motivation dimension between the two groups ($p = 0.26$). In both the mid-test ($p = 0.01$) and post-test ($p < 0.01$), the mean values of the motivation to learn dimension were significantly higher in the STEAM teaching group than in the regular teaching group (as shown in Figure 8).

In terms of attention dimension, it was found by multiple comparisons that in the group where the STEAM teaching concept was introduced, the mean values of attention dimension of pre-test, mid-test, and post-test of attention dimension increased sequentially, and all of them reached the level of significance ($p < 0.01$). In the group with conventional teaching, the mean value of the attention dimension of the pre-test was significantly lower than that of the post-test ($p < 0.01$). However, it was not significantly different from the mid-test ($p = 0.062$). The group simple effects analysis results showed that in the baseline, there was no significant difference in the mean values of the attention dimensions between the two groups ($p = 0.63$). In both the mid-test ($p = 0.02$) and post-test ($p < 0.01$), the STEAM instruction group had significantly higher mean values of attention dimensions than the regular instruction group (as shown in Figure 9).

Multiple comparisons found the independent learning intention dimension. In the group where the STEAM teaching concept was introduced, the mean values of the independent learning intention dimension of the pre-test, the mid-test, and the post-test of the independent learning intention dimension increased sequentially. All reached the level of significance ($p < 0.01$). In the group with conventional instruction, the mean value of the attention dimension of the pretest was significantly lower than that of the posttest ($p < 0.01$). However, it was not significantly different from the middle test ($p = 0.23$). The group simple effects analysis results showed no significant difference in the mean values of the independent learning intention dimension in the baseline between the two groups ($p = 0.88$). In both the mid-test ($p < 0.01$) and post-test ($p < 0.01$), the mean values of the attention dimension were significantly higher in the STEAM teaching group than in the conventional teaching group (as shown in Figure 10).

In terms of satisfaction dimension, it was found by multiple comparisons that the mean values of satisfaction dimensions of pre-test, mid-test, and post-test satisfaction dimensions of satisfaction dimensions increased sequentially in the group where the STEAM teaching concept was introduced, and all of them reached the level of significance ($p < 0.01$). In the group with conventional teaching, the

FIGURE 2
Xiapi posture of the Ming Dynasty "Shaolin Staff Method Elaboration" (Ma and Ma, 2015).

FIGURE 3
Immortal sits in a cave posture of the Ming Dynasty Shaolin Staff Method Elaboration (Ma and Ma, 2015).

mean value of the satisfaction dimension of the pre-test was significantly lower than the post-test ($p < 0.01$) but not significantly different from the mid-test ($p = 0.14$). The group simple effects analysis results showed that in the baseline, there was no significant difference in the satisfaction dimension means between the two groups ($p = 0.86$). In both the mid-test ($p = 0.07$) and post-test ($p < 0.01$), the STEAM teaching group had significantly higher satisfaction dimension means than the regular teaching group (as shown in Figure 11).

Regarding the disturbed emotion dimension, it was found by multiple comparisons that the mean values of the disturbed emotion dimension of the pre-test, mid-test, and post-test decreased sequentially in the group introduced to the STEAM teaching concept. All of them reached the level of significance ($p < 0.01$). The mean values of the disturbed emotion dimension of the pre-test were significantly higher than those of the mid-test and post-test under the regular teaching intervention ($p < 0.01$). However, the estimated marginal mean values of the disturbed emotion dimension of the group taught with the introduction of the STEAM concept decreased significantly faster. The group simple effects analysis results showed that at baseline, there was no significant difference in the mean values of the disturbed emotions dimension between the two groups ($p = 0.80$). At the mid-test, there was also no significant difference between the two groups in the disturbed emotion dimension ($p = 0.06$). In the post-test, there was a significant difference between the mean values of the disturbed emotion dimensions of the two groups ($p < 0.01$) (as shown in Figure 12).

The results of interviews with participants in the STEAM+ Shaolin staff teaching group

The qualitative insights from interviews shed light on students' learning encounters within the STEAM-integrated Shaolin Staff course. Beyond the controlled experiment, this research also involved interviewing 20 participants from the experimental group regarding STEAM-related instructional aspects. The ensuing feedback highlights their perceptions regarding the fusion of science, technology, art, and math within the context of the Shaolin Staff curriculum.

Participant A stated, "I felt that science was integrated into the teaching and learning activities in the Shaolin Staff program. The teacher teaches techniques while analyzing the principles of human kinesiology and mechanics. This enabled me to understand better and optimize my staff movements. In addition, my teacher helps us analyze the staff's effects on the body and study energy transformation and the role of force. If I lengthen the leverage of the staff, it will be more laborious for me to swing it.

Participant D said, "I had much fun using Mathematics in the Shaolin Staff course. By learning the angles and rotations of the staff, I began to realize the importance of mathematics in movement. I learned how to calculate angles and distances and apply geometric principles to improve my movements. This way of learning by combining math with actual movements has given me a new interest in math and helped me understand and apply math concepts more deeply in my Shaolin Staff studies.

FIGURE 4
Initial state of Xiapi.

FIGURE 5
Stage 1 of Xiapi.

Participant F said, "I appreciate using Art in the Shaolin Staff program. Through studying the history and culture of the Shaolin Staff, I began to appreciate and understand the artistic value of Shaolin Wushu. We learned physical expression and coordination in a class by imitating traditional Shaolin Staff movements and postures. While mastering my staff skills, I also developed my aesthetic ability. This way of incorporating artistic elements into my learning has given me a deeper interest in the Shaolin Staff and helped me develop my artistic perception.

Participant H said: I was pleasantly surprised by the use of Technology in the Shaolin Staff program. I could observe and evaluate my performance in real time through video analytics. This personalized feedback gives me a clearer understanding of my strengths and directions for improvement. At the same time, I improved my technical skills by learning to record and analyze my movements using technical tools. This way of learning by incorporating technology has increased my enjoyment of learning and made me more actively engaged in my studies.

Participant I said: For me, applying science, technology, art, and math to the Shaolin Staff course is a very integrated and interesting learning experience. Through studying these different disciplines, I have realized how interrelated and complementary they are. Science helps me to understand the principles of movement, mathematics helps me to calculate and optimize movements, art helps me to express

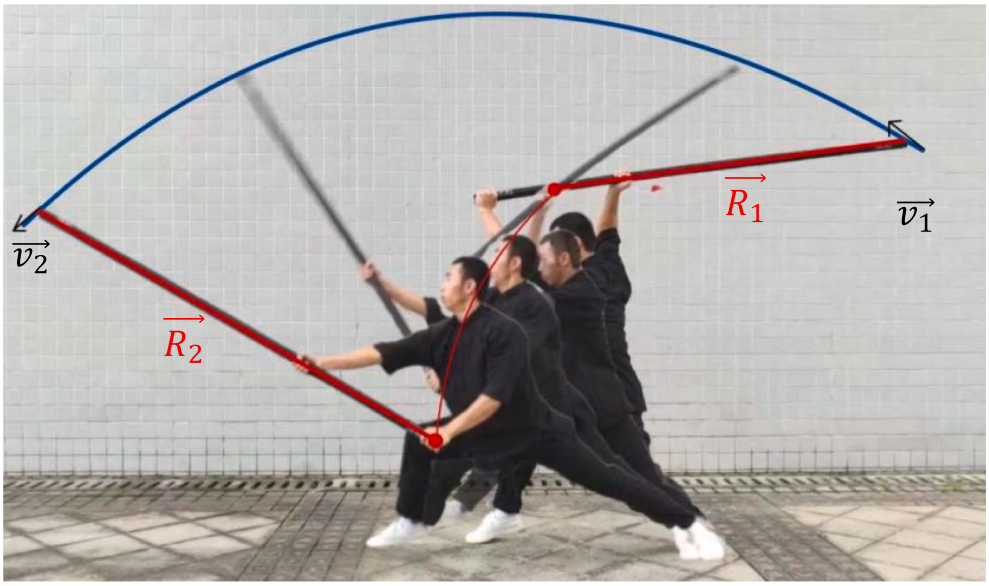

FIGURE 6
Stage 2 of Xiapi.

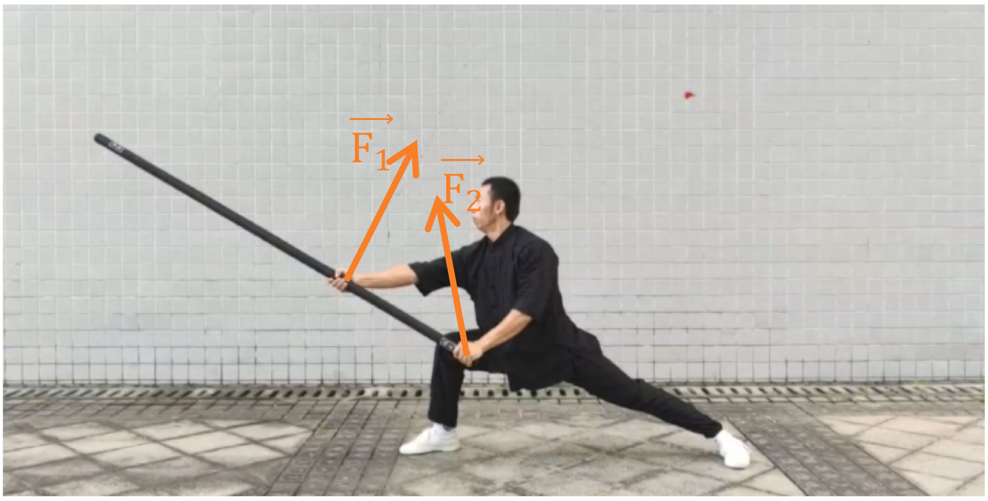

FIGURE 7
Stage 3 of Xiapi.

and coordinate body movements, and technology helps me to observe and improve my performance. This integrated approach to the disciplines has enabled me to develop myself holistically and given me new insights for my future studies and life.

In summary, students felt positive about applying math, art, and technology to the Shaolin Staff curriculum. This integrated application enabled students to understand and apply concepts from related disciplines more deeply and stimulated their interest in learning. Through the parsing of scientific principles, mathematical calculations and optimization, artistic expression, and application of technology, students gained a rich learning experience and increased engagement in learning. They gained competence in several areas. This further validates the effectiveness of applying STEAM teaching concepts to the Shaolin Staff program and provides a new teaching model for physical education.

Discussion and analysis

By applying STEAM teaching concepts and video analytics to the Shaolin Staff Technique course, students' dimensions of learning engagement can be effectively improved. STEAM teaching methods emphasize students' active participation and practical operation, making students the main body of learning, not just passive receivers

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TABLE 2 Comparison of experimental and control groups' learning engagement scores before and after the experiment (X ± SD).

Factor	Group	(M±SD)			Group main effect			The number of measurements main effect			Interaction effect of the number of measurements and group		
		Baseline	Three weeks	Six weeks	F0	bias $\eta^2$0	P0	F1	bias $\eta^2$1	P1	F2	bias $\eta^2$2	P2
Learning Motivation Dimension	T	2.37±0.40	3.19±0.46	4.06±0.31	11.39	0.23	0.02*	99.95	0.73	<0.01**	16.84	0.31	<0.01**
	C	2.55±0.60	2.82±0.44	3.26±0.33									
Attention Dimension	T	2.41±0.40	3.01±0.41	3.99±0.25	16.91	0.31	<0.01**	94.76	0.84	<0.01**	24.82	0.40	<0.01**
	C	2.48±0.47	2.72±0.38	3.07±0.38									
Self-Directed Learning Intention Dimension	T	2.46±0.51	3.15±0.21	3.92±0.22	27.55	0.42	<0.01**	78.40	0.67	<0.01**	11.47	0.23	<0.01**
	C	2.48±0.52	2.67±0.45	3.14±0.36									
Satisfaction Dimension	T	2.31±0.44	3.14±0.39	3.95±0.36	9.89	0.21	0.03	89.46	0.83	<0.01**	29.72	0.44	<0.01**
	C	2.58±0.55	2.81±0.34	3.09±0.33									
Disturbing emotional dimensions	T	3.47±0.30	2.97±0.34	2.21±0.30	7.54	0.17	<0.01**	145.26	0.89	<0.01**	14.60	0.28	<0.01**
	C	3.45±0.29	3.18±0.31	2.72±0.36									

"*" indicates $p < 0.05$; "**" indicates $p < 0.01$.

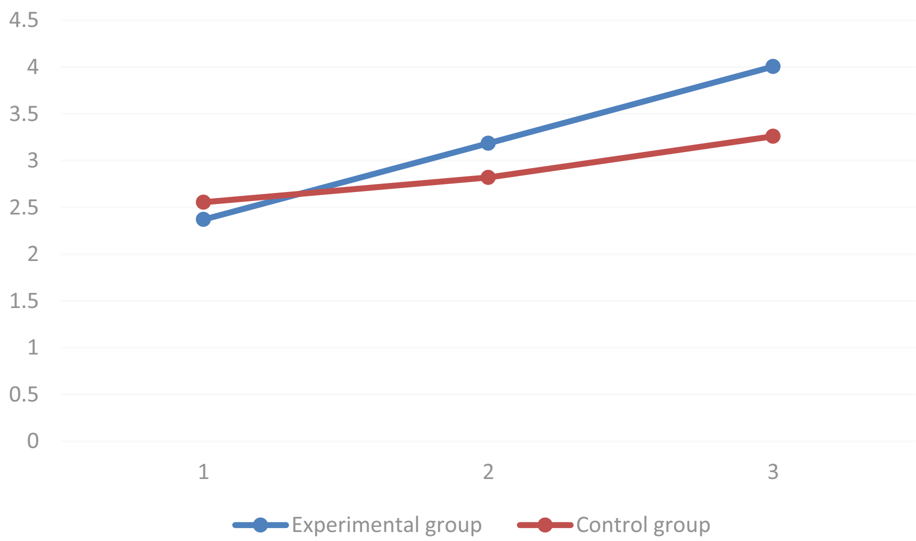

FIGURE 8
Comparison between experimental and control groups before and after the experiment of estimated marginal means of learning motivation dimensions.

(Madden et al., 2013). In this study, theoretical knowledge from different disciplines such as science, math, art, and physics is integrated into the teaching of Shaolin Staff, and the students not only master the Shaolin Staff technique itself but also learn the knowledge of other disciplines in the process of learning Shaolin Staff. In the process of learning the Shaolin Staff Technique, students not only mastered the technique itself but also learned other subjects. In addition to increasing students' interest and participation in learning, it further stimulated their exploratory mentality and ability to think and solve problems. It can be seen that the application of STEAM education concepts in physical education can integrate physical education with other disciplines and enhance the effectiveness of physical education. This study is also a positive attempt to improve traditional Chinese physical education's teaching concept and teaching effect. In studying the STEAM education concept to improve students' learning interest and participation, some scholars combine the STEAM education concept with Olympic education. This improvement in education can make students have a stronger interest in Olympic-related knowledge and Olympic events and begin to actively pay attention to the Olympic movement and learn the Olympic spirit (Li and Yuan, 2022). Therefore, integrating STEAM education concepts into educational sessions can recognize the diversity of student learning, increase student engagement in learning, and promote integration and transformation across subject areas (Allina, 2018). In the Shaolin Staff Technique course, students can understand and master the techniques and principles more deeply, stimulate learning interest and motivation, and improve learning participation through actual practice and operation. Video analysis technology plays a key role in the Shaolin staff fighting course. By analyzing students' movements through video, students can clearly understand their performance and progress in the learning process. Personalized feedback mechanisms motivate students and increase their commitment and engagement in learning. Students can observe and assess their movement skills, correct deficiencies, and see their progress. This personalized feedback boosts students' self-confidence, motivation, and learning engagement (Cauley and McMillan, 2010).

At the same time, the combination of STEAM teaching methods and video analytics can also improve students' aesthetic ability. Art is the foundation of all educational fields, and art education can break down the barriers between different educational fields by combining STEAM education concepts. It allows students to combine ideas and experiences to find new meanings, which develops their artistic creativity and aesthetic level and stimulates their aesthetic awareness and perception (Lee, 2014). The combination of art and science serves a unique purpose, enabling students to think outside the box to break down complex problems simultaneously. The corresponding solutions are then applied to the real world, providing a pathway to personal meaning-making and self-motivation (Land, 2013). Therefore, students are drawn to Shaolin culture while learning Shaolin Staff Techniques, thus developing and improving their aesthetic ability. This helps students appreciate and understand art and promotes the development of creative thinking and expression development.

Additionally, the analysis of technical movements in conjunction with physics demonstrates how this pedagogical approach improves student dimensions of learning engagement and athletic performance. Previous research on STEAM education has included integrating STEAM education with physics instruction. Creative integration education programs that utilize physical computing so that students can develop their creative problem-solving skills through computation, learn about science and other subjects in an integrated way, and increase students' interest in learning (Yin et al., 2020). Incorporating STEAM education concepts into physics instruction can foster the development of students' CT skills (Juškevičienė et al., 2021). Students can understand the scientific principles and mechanisms behind the movements by parsing the physics concepts of mechanics, kinematics, and kinetic energy transformation in movements. This theoretical knowledge increases students' knowledge and understanding of technical movements, enabling them to grasp the

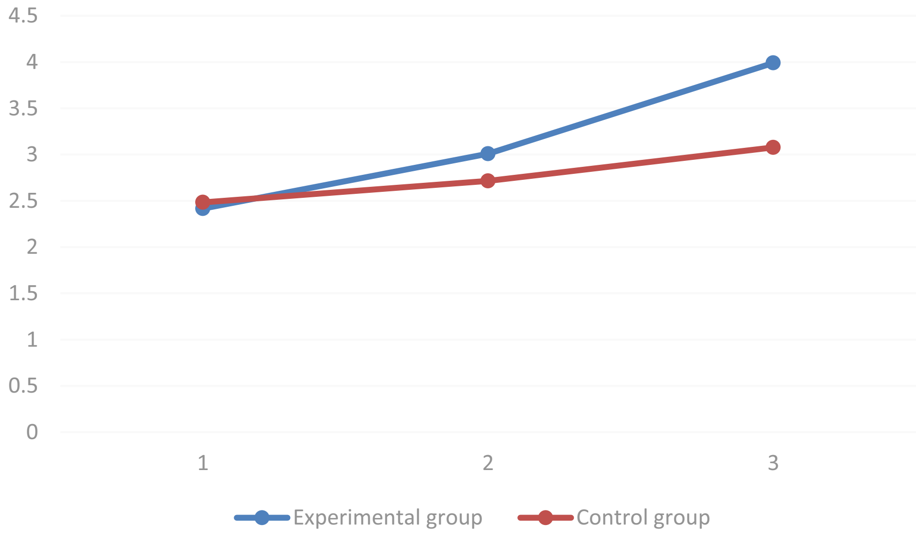

FIGURE 9
Comparison of the experimental and control groups before and after the experiment of estimating the marginal mean of the attention dimension.

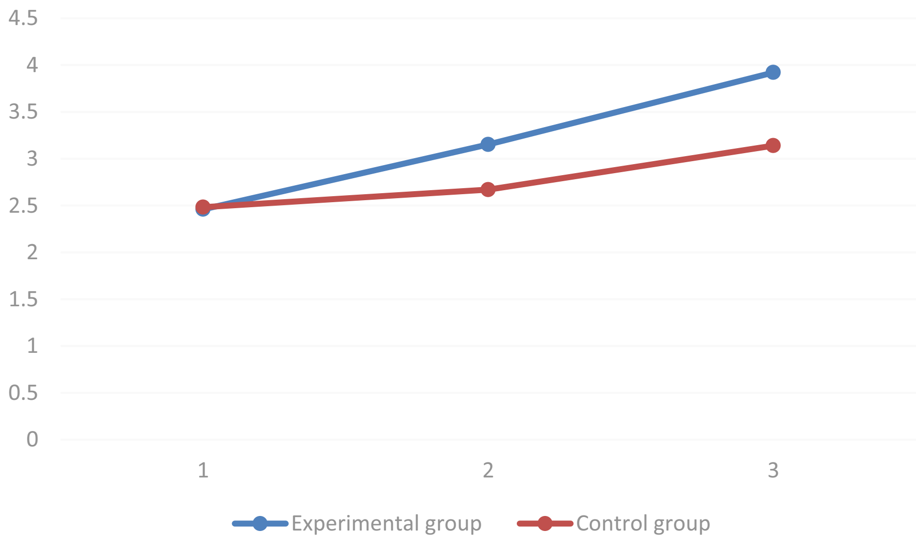

FIGURE 10
Comparison between the experimental and control groups before and after the experiment of estimating the marginal mean of the dimension of the autonomous learning intention.

key elements and execution of movements more accurately. Applying physics principles also gives students scientific thinking and analytical tools (Wang et al., 2015). Students can apply physics principles to analyze and evaluate their movement performance, analyzing factors such as the magnitude and direction of force changes in speed and acceleration and thus judging the accuracy and effectiveness of movements. In addition, through the guidance of the principles of physics, students can better master the essentials and techniques of movements and improve the quality of movement performance. This interdisciplinary approach aligns with education for sustainable development, which equips students with integrated knowledge and competencies to address sustainability issues (Annan-Diab and Molinari, 2017).

Generally speaking, the concept of STEAM education is being widely applied to teaching in various fields. Students can be exposed to the theoretical knowledge of other subjects while learning a certain subject, which in turn stimulates students' desire for exploration and interest in learning. This educational concept has gradually become the development trend of modern education. Integrating the STEAM concept into physical education may become a new direction for future development. In this paper, it can be seen that applying STEAM teaching concepts and video analyzing technology to the Shaolin Staff Technique course can improve students' participation in learning. The STEAM teaching method stimulates students' interest and motivation through active participation and hands-on practice, and the video analysis technology provides personalized feedback to promote

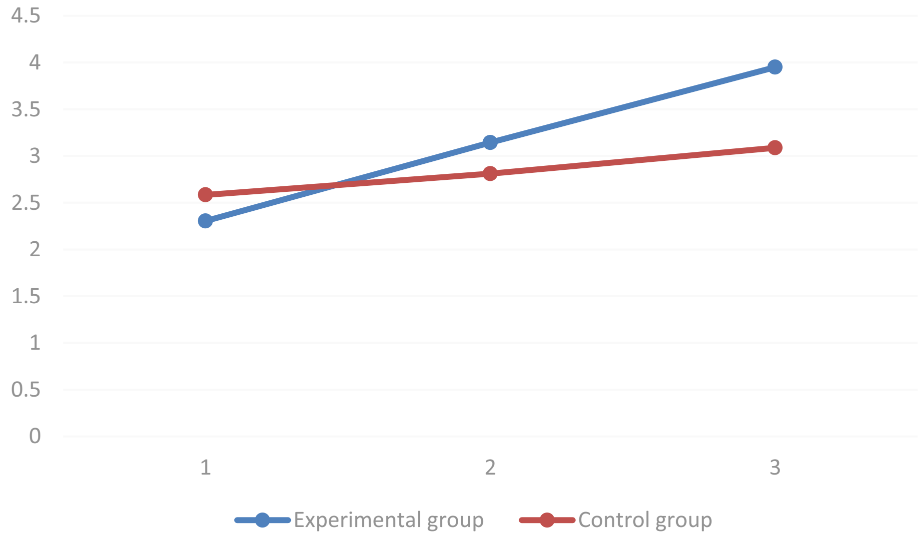

FIGURE 11
Comparison between experimental and control groups before and after the experiment of estimating the marginal mean of satisfaction dimension.

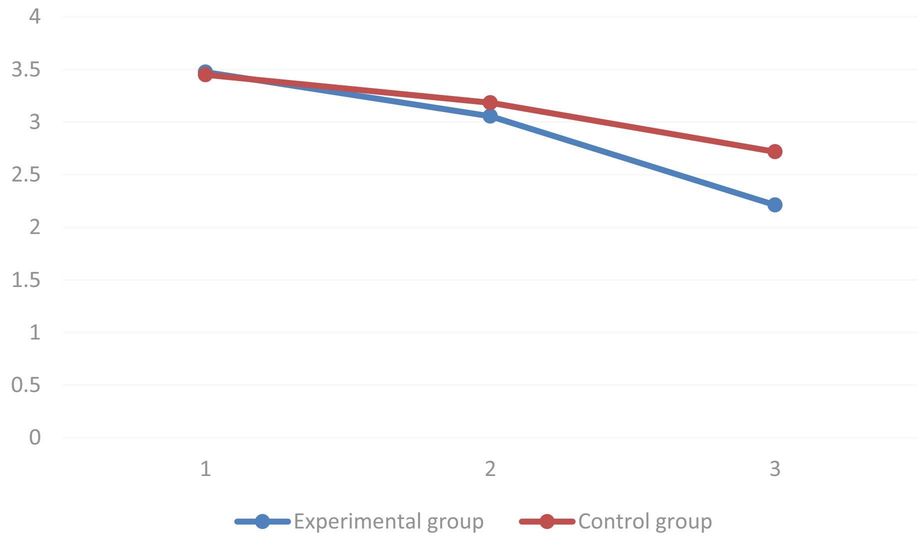

FIGURE 12
Comparison of the experimental and control groups before and after the experiment of the marginal mean of the interference mood dimension estimation.

students' self-confidence and engagement. At the same time, the analysis of technical movements in conjunction with the principles of physics enhances students' understanding and knowledge of the movements and improves the accuracy of their performance. These mechanisms interact with each other to provide students with a rich learning experience and stimulate their learning interests and engagement. Therefore, integrating STEAM teaching concepts, video analyzing techniques, and physics principles is an effective teaching approach to improve students' learning engagement and movement performance. While self-efficacy and self-directed learning are also important for student learning, this study narrowed its scope to assessing improvements in learning engagement. Further research could investigate how enhanced engagement may influence self-efficacy and self-directed learning abilities.

Limitations

This study found that the experimental group had significantly better learning outcomes than the control group, which may be related to the application of STEAM pedagogy. However, we did not test the potential mediating variables such as interest in learning, sense of engagement, etc. The STEAM approach emphasizes hands-on learning and interaction, which may increase students' interest and engagement and affect the learning outcomes. However, due to the study's limitations, we were unable to measure and test these mediating variables, which is a limitation of this study. We believe STEAM pedagogy may affect learning outcomes through mediating processes, but further research is needed to confirm the exact mechanisms. In the future, we will improve the research design, collect data on the mediating variables, and test the mediating effects by using path analysis and other methods to explain more comprehensively the influence of STEAM teaching on learning outcomes. This study lays the foundation for further research and raises questions that deserve further investigation.

Conclusions and recommendations

The study assessed how effectively the STEAM teaching model enhances student engagement in a Shaolin staff fighting course. Results reveal a significant increase in student learning engagement by blending science, technology, engineering, art, and math, along with video analytics for movement assessment and feedback. The utilization of a questionnaire to measure student learning engagement proved highly effective. This comprehensive approach not only nurtures interdisciplinary thinking but also aids in understanding intricate subjects such as sustainable development. Qualitative interviews provided evidence that the STEAM-integrated curriculum bolstered student motivation, knowledge application, skill enhancement, and overall learning experience in multifaceted manners.

Currently, China is actively promoting a strategy of cultural renaissance and advocating the modernization and transformation of traditional sports culture (Jinping, 2019). The teaching method explored in this study provides a way to improve traditional martial arts teaching. The Shaolin Wushu culture, as an important part of traditional Chinese culture, can improve students' learning participation through this teaching method and indirectly promote the inheritance and innovation of Shaolin Wushu culture. This teaching method provides students with a richer learning experience, which can help them understand and master Shaolin staff skills more deeply, and at the same time, cultivates their interest in and identification with Shaolin Wushu culture.

This study brings the following implications for current physical education practices:

Firstly, the existing physical education teaching has the problems of single content and boring form, which cannot stimulate the student's interest, and the diversity and comprehensiveness of the STEAM teaching method, as well as the intuitive image of video feedback, can make up for this shortcoming. Teachers should actively explore these new methods to make the curriculum more interesting.

Second, teachers need continuous professional development to improve their ability to utilize new technologies and theories. Educational administrations should provide teachers with training and resource support and encourage them to innovate the content and format of their teaching. At the same time, teachers need to upgrade themselves to better meet the diverse needs of their students.

Third, teachers should provide personalized instruction using video and scientific literacy to enhance student engagement during the teaching process. This requires educational institutions to create supportive environments that encourage teachers to explore new modes of teaching.

In conclusion, this study proves that the STEAM teaching method can effectively stimulate students' interest in learning and promote the inheritance and innovation of traditional sports culture. The future development of physical education requires the joint efforts of teachers, schools, and administrations to improve the quality of teaching and create a supportive atmosphere for teaching innovations to increase students' participation and promote the overall progress of physical education.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because the project is limited to curriculum-related activities for instructional purposes. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was provided by the participants or the participants' legal guardians/next of kin.

Author contributions

HC: Conceptualization, Funding acquisition, Investigation, Writing – original draft, Writing – review & editing. FR: Data curation, Methodology, Supervision, Funding acquisition, Writing – original draft. RC: Formal analysis, Project administration, Validation, Software, Writing – original draft. ZL: Resources, Visualization, Software, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Allina, B. (2018). The development of STEAM educational policy to promote student creativity and social empowerment. *Arts Educ. Pol. Rev.* 119, 77–87. doi: 10.1080/10632913.2017.1296392

Annan-Diab, F., and Molinari, C. (2017). Interdisciplinarity: practical approach to advancing education for sustainability and for the sustainable development goals. *Int. J. Manag. Educ.* 15, 73–83. doi: 10.1016/j.ijme.2017.03.006

Ballard, J. (2013). Learner engagement: a metric for learning. In 2013 IEEE 63rd Annual Conference International Council for Education Media (ICEM) IEEE.

Belbase, S., Mainali, B. R., Kasemsukpipat, W., Tairab, H., Gochoo, M., and Jarrah, A. (2022). At the dawn of science, technology, engineering, arts, and mathematics (STEAM) education: prospects, priorities, processes, and problems. *Int. J. Math. Educ. Sci. Technol.* 53, 2919–2955. doi: 10.1080/0020739X.2021.1922943

Carini, R. M., Kuh, G. D., and Klein, S. P. (2006). Student engagement and student learning: testing the linkages. *Res. High. Educ.* 47, 1–32. doi: 10.1007/s11162-005-8150-9

Cauley, K. M., and McMillan, J. H. (2010). Formative assessment techniques to support student motivation and achievement. *J. Educ. Strat. Issues Ideas* 83, 1–6. doi: 10.1080/00098650903267784

Halverson, L. R., and Graham, C. R. (2019). Learner engagement in blended learning environments: a conceptual framework. *Learning* 23, 145–178. doi: 10.24059/olj.v23i2.1481

Hsiao, P. W., and Su, C. H. (2021). A study on the impact of STEAM education for sustainable development courses and its effects on student motivation and learning. *Sustainability* 13:3772. doi: 10.3390/su13073772

Jia, Y., Zhou, B., and Zheng, X. (2021). A curriculum integrating STEAM and maker education promotes pupils' learning motivation, self-efficacy, and interdisciplinary knowledge acquisition. *Front. Psychol.* 12:725525. doi: 10.3389/fpsyg.2021.725525

Jinping, X. (2019). Firming cultural confidence, building a strong socialist cultural country. *Seek. Truth* 12, 4–12.

Juškevičienė, A., Stupurienė, G., and Jevsikova, T. (2021). Computational thinking development through physical computing activities in STEAM education. *Comput. Appl. Eng. Educ.* 29, 175–190. doi: 10.1002/cae.22365

Jyun, (2021). Talking about small class teaching. *J. Knowl.* 2, 8–9. doi: 10.14161/j.cnki.qzdk.2021.02.004

Land, M. H. (2013). Full STEAM ahead: the benefits of integrating the arts into STEM. *Proc. Comp. Sci.* 20, 547–552. doi: 10.1016/j.procs.2013.09.317

Lee, B. (2014). A study of STEAM education programs centered on art - focusing on developing teaching and learning plans for elementary and middle schools. *Korean Soc. Conver. Sci. Arts* 16, 311–321. doi: 10.17548/ksaf.2014.06.16.311

Lee, D. (2020). The effects of integrated physical education class on self-directed learning ability and physical education class attitude of middle school students. *Asia-Pac. J. Educ. Manag. Res.* 5, 41–48. doi: 10.21742/AJEMR.2020.5.2.06

Lee, D. J. (2021). The effect of STEAM-based physical education classes on middle school students' attitudes toward physical education classes and self-directed learning abilities[J]. *Iran. J. Public Health* 50, 938–948. doi: 10.18502/ijph.v50i5.6111

Li, J., and Yuan, L. (2022). The current situation and strategy of Olympic education for primary and secondary school students based on science-technology-engineering-art-mathematics education in the context of physical literacy. *Front. Psychol.* 13:910599. doi: 10.3389/fpsyg.2022.910599

Liu, P. (2014). A study of the Western stick (Doctoral dissertation, Shanghai Institute of Physical Education).

Ma, M., and Ma, L. (2015). Ancient Chinese Wuyi rare book series (upper series) book II. Qilu Book Company 1187

Madden, M. E., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., et al. (2013). Rethinking STEM education: an interdisciplinary STEAM curriculum. *Proc. Comp. Sci.* 20, 541–546. doi: 10.1016/j.procs.2013.09.316

Malecha, E. (2020). *The role of environmental education in steam education*. School of Education and Leadership Student Capstone Projects. 463. Available at: https://digitalcommons.hamline.edu/hse_cp/463

Mao, Yuan Yi. (1984). *Wu Bei Zhi*. Brooklyn: Hua Shi Publishing House.

Morado, M. F., Melo, A. E., and Jarman, A. (2021). Learning by making: a framework to revisit practices in a constructionist learning environment. *Br. J. Educ. Technol.* 52, 1093–1115. doi: 10.1111/bjet.13083

Naiqing, S., and Xin, G. (2021). Analysis of the connotation, value, and theoretical framework of STEAM education evaluation in primary and secondary schools. *Educ. Sci. Res.* 10, 47–53.

Peng, H., Ma, S., and Spector, J. M. (2019). Personalized adaptive learning: an emerging pedagogical approach enabled by a smart learning environment. *Smart Learn. Environ.* 6, 1–14. doi: 10.1186/s40561-019-0089-y

Ramadhan, A. (2021). Development of STEAM-based physical education learning model to improve physical fitness of elementary school students. In 2021 Universitas Riau international conference on education technology (URICET) IEEE.

Schunk, D. H., and Zimmerman, B. J. (Eds.). (1994). *Self-regulation of learning and performance: issues and educational applications. 1st edn.* (London: Routledge).

Seo, K. K., and Gibbons, S. (2019). Learner engagement in teacher education. Oxford Research Encyclopedia of Education. doi: 10.1093/acrefore/9780190264093.013.263,

Shahar, M. (2001). Ming-period evidence of shaolin martial practice. *Harv. J. Asiat. Stud.* 61, 359–413. doi: 10.2307/3558572

Shanxi Sports Science Institute. (2021). The best indicator of health and fitness - cardiorespiratory fitness (II) - physical fitness-fitness-Shanxi sports bureau website [EB/OL]. Available at: https://tyj.shanxi.gov.cn/bsfw/tzjs/202106/t20210618_1365184.shtml.

Sun, L. (2022). An intervention study of college students' learning engagement in a blended learning environment (Doctoral dissertation Northeast Normal University) Available at: https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CDFDLAST2023&filename=1023460990.nh

Tang, H. (2008). *Shaolin wudang kao - taijiquan and neijiaquan - neijiaquan*. Taiyuan: Shanxi Science and Technology Press; Shanxi Publishing Group, 62.

Wang, J., Guo, D., and Jou, M. (2015). A study on the effects of model-based inquiry pedagogy on students' inquiry skills in a virtual physics lab. *Comput. Hum. Behav.* 49, 658–669. doi: 10.1016/j.chb.2015.01.043

Wenchao, Z., Ning, H., and Lei, Y. (2022). Exploration of STEAM education inheriting traditional culture. *Mod. Educ. Technol.* 5, 42–48.

Wu, Z. (2023). A comparative review of STEAM (science, technology, engineering, arts, and mathematics) international development and implementation. *Jurnal VARIDIKA* 1, 33–53.

Yarime, M., Trencher, G., Mino, T., Scholz, R. W., Olsson, L., Ness, B., et al. (2012). Establishing sustainability science in higher education institutions: towards an integration of academic development, institutionalization, and stakeholder collaborations. *Sustain. Sci.* 7, 101–113. doi: 10.1007/s11625-012-0157-5

Yin, Y., Hadad, R., Tang, X., and Lin, Q. (2020). Improving and assessing computational thinking in maker activities: The integration with physics and engineering learning. *J Sci Educ Technol.* 29, 189–214. doi: 10.1007/s10956-019-09794-8

Yuan, Y., Ji, X., Yang, X., Wang, C., Samsudin, S., and Omar Dev, R. D. (2022). The effect of persistence of physical exercise on the positive psychological emotions of primary school students under the STEAM education concept. *Int. J. Environ. Res. Public Health* 19:11451. doi: 10.3390/ijerph191811451

Zhu Liming, W., Lisha, S. N., and Jin, H. (2023). Deep learning under the concept of STEAM education: implication, value, and form of expression. *Educ. Sci. Res.* 1, 73–79.

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Developing the theoretical model of Chinese physical education teachers' health communication competence: based on grounded theory

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Background: Physical education teachers' health communication competence is a key factor in health promotion. Although health communication is a multidisciplinary field, medical practitioners are the primary focus of health communication research, whereas physical education teachers are marginalized. Therefore, this study proposes a theoretical model of health communication competence for physical education teachers.

Methods: This qualitative research utilized interviews as the primary data collection method. Purposeful sampling was employed to select participants, including university teachers, primary and secondary school teachers, and health education professionals from diverse regions of China. A total of 31 participants were interviewed through two focus groups ($N = 15$) and individual semi-structured interviews ($N = 16$). Grounded theory was used to analyze and code the collected interview materials.

Results: The health communication competence of physical education teachers consisted of three main categories, 10 subcategories, 30 concepts, and 240 statement labels. The three main categories were as follows: (i) foundations of health communication knowledge and skills (this category encompassed three subcategories, namely sport and health knowledge reserve, health beliefs, and health behaviors); (ii) health communication perception competence (this category included two subcategories, namely health risk and crisis perception competence and communication audience perception competence); and (iii) practical competence of health communication (this category consisted of five subcategories, namely language expression competence, organizational and design competence, utilization of new media tools competence, communication content selection and processing competence, and professional skills).

Conclusion: The theoretical model of health communication competence in this study provides a foundation for the involvement of physical education teachers in health communication work. It can serve as a reference for the development of both pre-service health education courses and in-service training systems for physical education teachers. Future research can expand the sample size and geographic coverage to further validate the applicability of the findings.

Additionally, investigating the factors influencing the formation of the identified competencies is recommended.

KEYWORDS

health communication competence, physical education teacher, grounded theory, focus group (FG), model development

1 Introduction

Health communication plays a crucial role in promoting healthy lifestyles and enhancing public health literacy (1–3). Additionally, it serves as a focal point in academic discourse. Although health communication has characteristics that span across various disciplines, research in this field predominantly takes place in hospital settings. Examples include controlling smoking or promoting vaccine literacy (4). The primary objective of these initiatives often relies on medical professionals, such as doctors or nurses (5). China believes that exercise is the best medicine; therefore, physical education has been seen as a potential means of health communication. As for the young generation, social media has become the most popular space for them to acknowledge health information and foster health communication (6). As social media is a space where user-generated content (UGC) is generated, health-related communication is problematic, especially when pseudoscientific or commercial information is prevalent (7). In light of the prevalence of health communication in social media, and the threat of "bad money driving out good money," accurate scientific health communication has become increasingly important.

As physical health among the youth has declined dramatically in recent years (8–11), current research offers significant guidance regarding health communication in physical education, focusing on curriculum change (12), and the development of scientific standards (13). The reform of physical education curriculum means encouraging students to establish healthy lifestyles and values, which requires physical education teachers not only to have professional knowledge in the field of physical education, but also to have knowledge in health education, healthcare, and other discipline. Therefore, physical education teachers need to have certain interdisciplinary teaching abilities (14). With respect to the development of scientific standards, several policies have been launched, including the "Guidelines on Physical Activity and Sedentary Behavior" from the World Health Organization in 2022 (15), "Guidelines on Physical Activity and Sedentary Behavior for Chinese Residents," and "Guidelines for the Evaluation of Health Literacy of Chinese Residents" from the Chinese government (16, 17). Regardless of the focus, be it curriculum change or the development of scientific standards, the competence of physical education teachers in health communication always emerges as pivotal. The domain of physical education and health is where a physical education teacher's expertise, both in terms of knowledge and effective teaching practice, is deeply rooted. In essence, the competence of physical education teachers in health communication stands as a key determinant of the success of these health communication policies.

For the objectives of health communication research, medical professionals, including those such as doctors, nurses, and general practitioners, have been central. Their professional development trajectories and models of health communication competencies have been scrutinized (18). Studies have attempted to identify specific health communication competencies for diverse groups. Coleman et al. (13) employed the Delphi approach to establish a theoretical framework for health literacy practice education among in-service medicine practitioners (19). Timothy (20) conducted a questionnaire survey to assess health communication competencies among preservice health professionals at the graduate level. He found that specific elements, such as media, interaction, and health promotion theories, form the core of health communication competence. Park et al. (21) conducted a quantitative study to explore the ideal health communication competence for in-service health educators. The study identified health theoretical foundation, communication skills, and interdisciplinary abilities as key attributes of health communication competence (22).

Rogers introduced the concept of health communication, which essentially refers to any form of human interaction that pertains to health-related content (23). From Rogers' definition, it is apparent that health communication should span across more relevant disciplines and groups. However, existing health communication research reflects interdisciplinary studies and is primarily a combination of the fields of medicine and communication. Physical education, actively promoting health, is an essential component of any comprehensive health system. However, there is limited research on physical education teachers and their role in promoting health in existing health communication studies. Within the sphere of health communication concerning physical health issues, physical education teachers are more specialized than healthcare professionals such as doctors and nurses. In China, physical education teachers not only need to acquire knowledge in physical education but also study subjects such as exercise physiology, sports health science, sports anatomy, and sports biochemistry. Given the substantial population of in-service and preservice physical education teachers in the 317 universities offering physical education teacher education courses out of 2,688 universities in mainland China (24), they can potentially reach a broader spectrum of professions and individuals when engaging in health communication.

Despite the abundance of research in the field of health communication conducted from various perspectives and proposed resolutions, the role of physical education teachers remains overlooked. Furthermore, the majority of studies are predominantly macro-level, leaving a gap in translating these findings into practical strategies for unique groups, such as physical education teachers engaging in health communication collaboratively. This void constrains the effectiveness of health communication initiatives. Importantly, questionnaire surveys have dominated health communication competence research. In most cases, questionnaire surveys rely on relatively simple questions, which are unlikely to yield complex information (25), while grounded theory is especially useful when the information to be gathered is varied or complex, or when the study is exploratory (26). Since physical education is a complex social phenomenon (27), grounded theory is widely accepted in the field, such as physical activity (21), physical education courses (28), and teacher's professional development (29). Therefore, this study aims to address this gap by investigating the health communication competence of physical education teachers using grounded theory. This model seeks to offer practical guidance for physical education teachers involved in health communication and introduce a fresh perspective for research in the field of health communication.

2 Materials and methods

The study employed grounded theory, which is widely used in research on physical education teachers (30–32). Grounded theory is an approach that avoids preconceived notions and follows a bottom-up process of theory development, making the theoretical model constructed more objective (33). It is characterized by its focus on practice, reliance on empirical evidence, and foundation in real-world experiences. As a typical qualitative research method, grounded theory not only possesses the holistic characteristics common to all qualitative research methods but also assists researchers in delving deeply into the experiences, beliefs, and emotions of the research subjects (29). This method gradually facilitates a more profound understanding and interpretation. The bottom-up approach to theory generation inherent in grounded theory ensures the thoroughness and authenticity of the constructed theory (34). Therefore, the theoretical models developed through grounded theory are more intricate, offering better practical guidance and making them suitable for constructing theoretical frameworks (26). The reliability and accuracy of the original data have a significant impact on the results of grounded theory. These characteristics are particularly valuable in the current context in which there is a lack of research on the health communication competence of physical education teachers. Grounded theory can help physical education teachers quickly establish a comprehensive awareness of the competence needed for health communication, enabling a rapid immersion into health communication practices.

2.1 Participants

The reliability and accuracy of the original data have a significant impact on the results of grounded theory. The requirements of grounded theory for interviewees were reflected in three aspects: (i) the number of participants; (ii) the approach of interviews; (iii) the representativeness of interviewees. For the number of participants, according to Guest et al. (35), 12 interviews were sufficient to reach data saturation. When considering the huge population size in the context of China, additional interviews provided more nuanced insights. Hence, a total of 31 participants were selected by a purposive sampling approach in this study. Specifically, 16 participated in individual interviews and the remaining 15 were divided into two focus groups to gather the data.

The first focus groups were conducted with nine participants, and six participants joined in the second focus group sessions. Based on the limited research available regarding the health communication competence of physical education teachers, the number of interviews provides another reason to construct a theoretical model of the health communication competence among Chinese physical education teachers. For the approach of interview, qualitative research emphasizes in-depth exploration and understanding of participants' experiences, perspectives, and insights (36). By conducting individual interviews and focus groups in the field of physical education teacher, we can gather a rich and diverse range of data from both individuals and group discussions and interactions that may generate additional insights (37).

The representative questions were mainly based on the results of grounded theory. In order to enhance the scientificity and practicality of the theoretical model constructed by the research institute, this study not only selected primary and secondary school physical education teachers as interviewees, but also selected research scholars in health communication and health communication practitioners (nurses) as interviewees (see Table 1 for details of the participants). The inclusion criteria of the participants included: (i) a minimum of 2 years teaching experience in physical education; or (ii) a minimum of 2 years working experience in health communication as health education professionals. Prior to the interviews, informed consent was obtained, and the interview process was recorded with the participants' permission.

TABLE 1 Information about the interview participants ($N = 31$).

Interview participants ($N = 31$)		
Teaching experience (years)	0–10	20 (65%)
	10–20	2 (6%)
	20–30	4 (13%)
	30–40	5 (16%)
Degree	College diploma	1 (3%)
	BEd	9 (29%)
	MEd	16 (52%)
	PhD	5 (16%)
Title	Second-level teacher	15 (49%)
	First-level teacher/ assistant professor	4 (13%)
	Associate senior teacher/ associate chief nurse/ associate professor	10 (32%)
	Professor	2 (6%)
Region	Northern China	2 (6%)
	Eastern China	19 (61%)
	Central China	1 (3%)
	Southwest China	6 (20%)
	Northwest China	3 (10%)
Interview method	Individual interview	16 (52%)
	Focus group interview	15 (48%)

The professional titles of Chinese primary and secondary school teachers are divided into five main levels: third-level teachers, second-level teachers, first-level teachers, associate senior teachers, and senior teachers. Professor in university is equal to senior teacher in primary and secondary school. Associate professor is equal to associate senior teacher or associate chief nurse. Assistant professor is equal to a first-level teacher.

TABLE 2 Interview questions ($N = 4$).

No.	Interview questions
1	Have you ever engaged in health communication with your family and friends? If so, please provide examples?
2	How do you define the health communication competence of physical education teachers? What aspects are included in this competence?
3	What roles and responsibilities do you think physical education teachers have in health communication? How do they contribute to promote pupils' healthy behaviors and awareness?
4	What are the main challenges that physical education teachers face in health communication? In which areas do they need further improvement?

2.2 Interview

The ethical review was approved by the author's institution. The interview questions were informed by relevant literature reviews (38–40), as well as the insights that were gathered from three experts before the interviews began. A physical education expert and two experts in the fields of communication and health education were selected to participate in this pilot study. As a result of their expertise, we refined the interview outline to ensure that the interview questions were aligned with the research inquiries that were being addressed in the interview. The study ultimately designed four open-ended questions (see Table 2), which were mainly focused on two aspects: (i) the interviewees' experiences in health communication and (ii) the dimensions of health communication among physical education teachers. Owing to geographical distances, respecting the subjective preferences of the interviewees, and the lockdown policy related to the COVID-19 pandemic in China, interviews were primarily conducted online.

Each interview took 45–60 min and adhered to the guidelines established by the interview guidance on sports, exercise, and health (25, 27, 41): (1) the list of questions should be as concise as possible, incorporating probing questions to extract additional information from the participants and delve deeper into their accounts, responses, and stories. Our study's probing questions were developed based on the interview guidance provided by Clegg and Butryn (19) in the field of physical education (42). For instance, the first interview question in our study is, "Have you ever engaged in health communication with your family and friends? If so, please provide examples." Following Clegg and Butryn's guidance, we developed sub-questions such as: how has such engagement with friends/family affected you? What thoughts stood out for you in a special moment during health communication? How do you feel when you imagine engaging in health communication with your family or friends, even if you have not done so yet? (2) Kvale (43, p.103) suggests that the sample size of qualitative research is not one that should be determined at the beginning of a study (44). Additionally, Baker (45) notes the basic rules of how to become a good interviewer in social science: the researcher should be committed at every interview to spend sufficient time to gather enough data. Therefore, the 45–60 min allocated for each interview was determined based on the conversations with interviewees, concluding each session when saturation was achieved. Owing to the dynamic nature of conversations in focus groups and the emergence of unexpected thoughts during group interactions (25), focus group sessions in our study lasted slightly longer than individual interviews.

2.3 Data analysis

After the interviews, the audio recordings were first converted into text using Microsoft Word software. The transcriptions were then organized and read through, and irrelevant content was removed. Through both individual interviews and focus groups, the researchers compiled a total of 18 interview transcripts, amounting to 44,736 words. Next, the interview data were analyzed using the three-level coding approach of grounded theory with Nvivo19 software. The coding process involved open coding, axial coding, and selective coding (26). This analysis aimed to construct a theoretical model of health communication competence for physical education teachers in China.

2.3.1 Open coding

Open coding is the process of the initial screening and analysis of the collected interview data in the research. It can be understood as the process of "labeling" the data. During this process, irrelevant content was removed to ensure that the coding was not influenced by subjective understanding or existing research. Relevant statements were analyzed and extracted to form labels and categories for related concepts.

Step 1: Labeling involves the process of transforming interview data into labeled statements, as described in Table 3. The labels in the text follow the naming convention of "EN + label statement," for example, "E1 You should have healthy behaviors and lifestyle." A total of 240 labeled statements were generated (see Table 4). The labels indicate that the interviewed teachers and experts primarily focused on several aspects of the components of health communication competence for physical education teachers, such as language expression, knowledge reserves, and the use of information technology devices.

Step 2: Conceptualization. Through comparing, refining, analyzing, and integrating the labeled statements, similar or related contents were merged, further refining the 240 labeled statements generated in the labeling process. In this study, 30 concepts were integrated from the 240 labeled statements. The concepts are presented using the format "DN+ Concept Name." For example, D1 Health Lifestyle. Detailed examples of the process from labeling to conceptualization can be found in Table 5, and the results of conceptualization are shown in Table 6.

Step 3: Categorization. Categorization was achieved through continuous analysis, comparison, and induction of the 30 concepts generated. From these concepts, categories were extracted, emphasizing the need for high exclusivity among various categories and high representativeness of the concepts within each category.

TABLE 3 Examples of the tagging process for the interview data.

Type	Interview material	Labeling
Focus group interview 1	In subjects like emergency safety, preparedness, and risk mitigation, it is necessary for you to be able to guide students on what to do. Therefore, when imparting this knowledge to students, you should possess the necessary knowledge and skills.	E4 Know how to guide students to do so when an emergency situation happens E5 You should possess health communication relevant knowledge and skills
Individual interviewee, Individual interview materials 16	When you have a strong grasp of professional knowledge, it becomes easier for others to accept the health information you communicate. It is important to prioritize simplicity and ease of learning when conveying this knowledge. From a wide range of content, you should select the ones that are simple and easy to understand, as this will yield better results. Additionally, it is essential to stay informed about currently popular and trending fitness activities. This knowledge will accelerate the dissemination process because these activities are both easy to learn and engaging, leading to a rapid spread of information.	E108 Possess strong professional knowledge to enhance credibility E109 Select simple and easy-to-learn content from a variety of materials E110 Know what popular and trending fitness activities are currently

TABLE 4 Labeling results.

Tagged labels	Tagged labels
E1: It requires a healthy behavior and lifestyle	E121: You need to know the mainstream communication platforms
E2: The basic knowledge is important	E122: You should understand how to train overall physical fitness
E3: Skills are also important	E123: Can design various exercise methods
E4: Know how to guide students to do so when an emergency situation happens	E124: Can coordinate his spare time or his time after work
E5: You should possess health communication relevant knowledge and skills	E125: It requires knowledge and ability to prevent some of the most basic and common diseases
E6: Has a relatively rich understanding of health education and health communication	E126: The knowledge of sports and health in books is a fundamental requirement for communication

For the specific date, see Appendix Table A1.

TABLE 5 Example of the process from raw materials to conceptualization.

Conceptualization	Labeling	Interview material
D6: Can use the internet for communication	E18: Should catch the fast train of epoch development E19: Should be able to grasp the peak period of short video platforms such as TikTok and Kwai E20: Have the ability to apply information technology	Contemporary physical education teachers should hop on the fast-moving train of technological advancements to effectively disseminate health knowledge. It is crucial to leverage popular short video platforms like TikTok and Kwai to ensure the rapid spread of our knowledge. This requires physical education teachers to have the ability to utilize information technology and to filter through various sources of information.
D8: Having passion for health communication	E17: Should have a pure intention of helping people engage in healthy behavior	Currently, much of the available health information is driven by profit and heavily influenced by commercial interests. Therefore, it is important for physical education teachers to maintain pure intentions and prioritize public welfare when engaging in health communication.

TABLE 6 Conceptualization results of 240 label statements.

Conceptualization numbers	Tagged labels
D1: Having a healthy lifestyle	E1, E43, E53, E102
D2: Possessing relevant knowledge of sports and health	E2, E5, E6, E7, E8, E11, E35, E49, E58, E73, E79, E90, E91, E108, E114, E122, E125, E126, E128, E132, E167, E178, E179, E186, E187, E197, E198, E206, E207
D3: Having relevant communication skills	E3, E34, E54, E55, E97, E100, E103, E168, E177
D4: Leading by example	E12, E13, E14, E44, E84, E85, E156, E160, E181, E193, E195, E238

For the specific date, see Appendix Table A2.

TABLE 7 Example of the categorization process of raw materials.

Categorization	Conceptualization	Labeling	Interview material
C6: Language expression competence	D16: Possessing good language expression and organizational skills	E80: Making others understand is essential	I believe there is a need for effective verbal expression because, in reality, you have to communicate with others. Sometimes, we have to convey something to others and ensure that they understand it. It all comes down to how you organize and articulate your language. You may possess knowledge yourself, but when it comes to conveying it to others, it may not be as straightforward.
		E81: The organization and expression of language are crucial	
	D24: Having the ability to facilitate communication and collaboration	E104: Expand beyond the school environment and have the ability to communicate and collaborate	If we aim to expand beyond the school environment, it is essential for physical education teachers to engage in communication and collaboration with the community.

TABLE 8 Categorization results of 30 concepts.

Categorizations	Conceptualization	Label numbers
C1: Sports and health knowledge reserve	D2: Possessing relevant knowledge of sports and health	29
	D18: Demonstrating professionalism when communicating	11
C2: Health beliefs	D8: Having passion for health communication	8
	D26: Being adaptable to different roles	4
C3: Healthy behavior	D1: Having a healthy lifestyle	4
	D4: Leading by example	12
C4: Health risk and crisis perception competence	D5: Seizing special opportunities for health communication	9
	D27: Can seize current hot topics	5

For the specific date, see Appendix Table A3.

TABLE 9 Results of the main axis coding for 10 categories.

Subcategories	Subsidiary categories
B1: Foundation of health communication knowledge and skills	C1: Sports and health knowledge reserve
	C2: Health beliefs
	C3: Healthy behavior
B2: Health communication perception competence	C4: Health risk and crisis perception competence
	C5: Communication audience perception competence
B3: Practical competence of health communication	C6: Language expression competence
	C7: Organizational and design competence
	C8: Utilization of new media tools competence
	C9: Communication content selection and processing competence
	C10: Professional skills

Through this process, a total of 10 categories were identified. The categories are presented using the format "CN + Category Name," e.g., "C1 Sports and health knowledge reservoir." Detailed examples of the categorization process can be found in Table 7, and the complete results of categorization are shown in Table 8.

2.3.2 Axial coding

Axial coding is the second level of coding in the grounded theory three-level coding process. It builds upon the concepts and categories formed in the initial coding stage. In axial coding, the focus of our study was on analyzing the causal relationships, interactive strategies, and phenomena among the categories obtained from the open coding process. In this study, three main categories, denoted as BN (Basic Categories) followed by their names, were identified. The three main categories were as follows: B1: Foundation of Health Communication Knowledge and Skills, B2: Health Communication Perception Competence, and B3: Practical Competence of Health Communication (refer to Table 9). The category "B1 Foundation of Health Communication Knowledge and Skills" includes three subcategories: C1: Sport and health Knowledge Reserve, C2: Health Beliefs, and C3: Health Behaviors. The category "B2: Health Communication Perception Competence" consists of two subcategories: C4: Health

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Risk and Crisis Perception Competence and C5: Communication Audience Perception Competence. The category "B3: Practical Competence of Health Communication" encompasses five subcategories: C6: Language Expression Competence, C7: Organizational and Design Competence, C8: Utilization of New Media Tools Competence, C9: Communication Content Selection and Processing Competence, and C10: Professional Skills. These main categories and subcategories represent a comprehensive and condensed theoretical model of health communication competence for physical education teachers, derived from the in-depth understanding of the research participants.

2.3.3 Selective coding

Selective coding is the final process in constructing the grounded theory three-level coding. Its main purpose is to distill the "core concept" that can encompass all the concepts (26). This core concept must have a unifying nature and be able to encompass the majority of the research findings. Through in-depth analysis of the 10 subcategories and three main categories formed, combined with the concepts and labels identified in the previous coding process, and considering the original interview content, the core category that emerged, encompassing all other categories, was "Health Communication Competence of Physical Education Teachers." This study followed the three-level coding process in grounded theory, progressing through the processes of labeling, conceptualization, and categorization in the first-level coding, main categorization in the second-level coding, and core categorization in the third-level coding. The three-level coding resulted in the theoretical model of health communication competence for physical education teachers, which includes three main categories, 10 subcategories, 30 concepts, and 240 statement labels (see Figure 1; Appendix A).

2.4 Trustworthiness

To ensure the credibility of the components of physical education teachers' health communication competence, a coding process was conducted first for individual interviews, with the data from two focus group coded after the completion of the individual interviews. This process did not result in the emergence of new concepts or categories. Additionally, three sets of materials were reserved in advance during the coding process of individual interviews. After completing the coding, these reserved materials were coded as well, but no new concepts or categories were identified. Finally, the data collected from the individual interviews were coded, followed by the selection of one interviewee for further interview coding. However, no new concepts or categories were discovered. Therefore, the constructed framework for physical education teachers' health communication competence in this study was considered saturated and aligned with the research requirements.

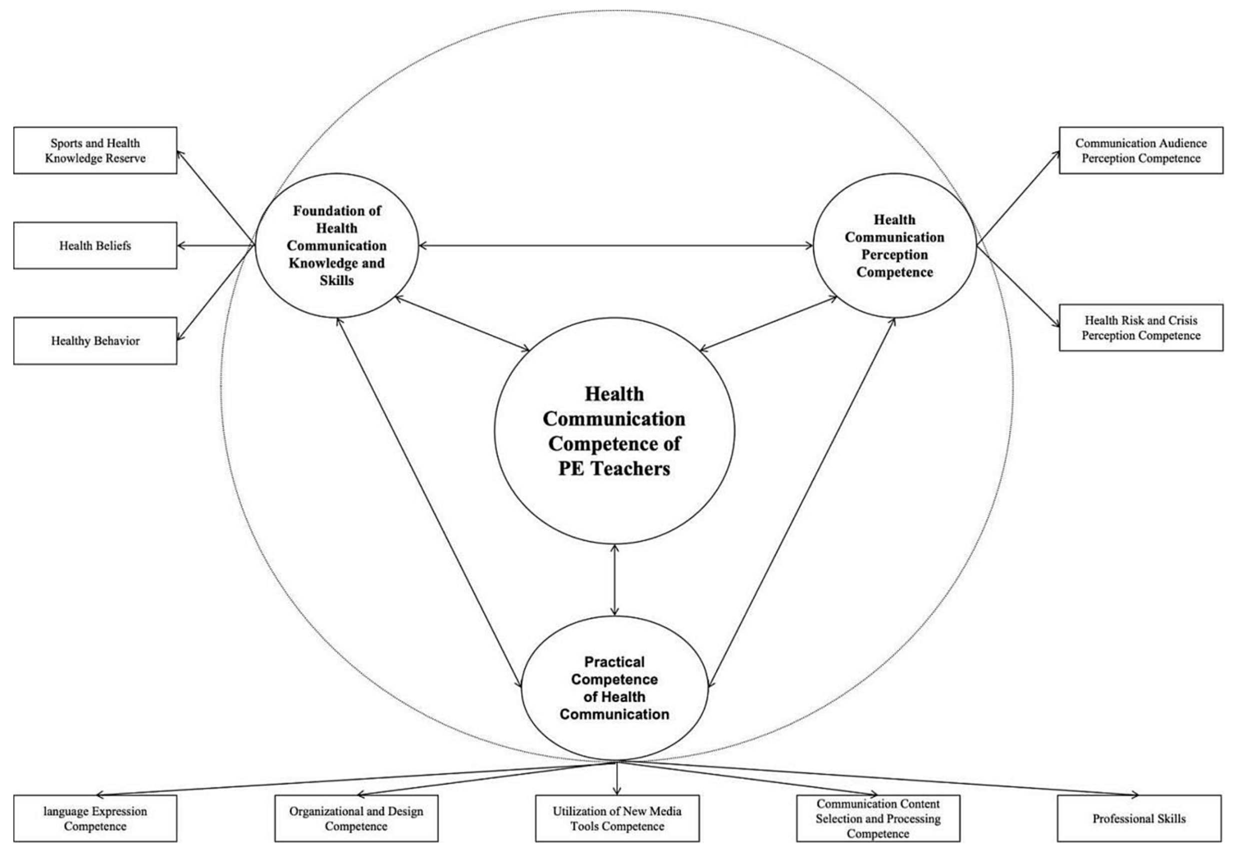

FIGURE 1
The health communication competence of physical education teachers.

3 Results

Based on the three-level coding process of grounded theory, it can be observed that the health communication competence of physical education teachers can be primarily described through the overall framework of Basic Health Communication Knowledge and Skills, Perception of Health Communication, and Practical Ability of Health Communication. The combination of these main categories and subcategories provides a comprehensive depiction of the theoretical model of health communication competence for physical education teachers.

3.1 The foundation of health communication knowledge and skills

From the constructed categories, it is evident that physical education teachers need to possess a strong reservoir of physical education and health knowledge to communicate health effectively to promote healthy behaviors and awareness in pupils. The need for physical education and health knowledge was also mentioned frequently by participants.

3.1.1 Sports and health knowledge reserve

When engaging in health communication, physical education teachers primarily focus on content related to physical education and health. Health knowledge, particularly physical education health knowledge, is highly time-sensitive, and topics related to health also entail a certain level of professional expertise. Therefore, physical education teachers can only carry out health communication successfully when they have acquired a certain theoretical foundation. This point is raised in response to the prevailing issue of "pseudo-experts" in the field of health communication.

> "*To promote physical education and health, it is essential for us to possess relevant knowledge in this field. Teachers must understand which exercise can lead to specific outcomes of health promotion. Therefore, equipping professional knowledge in physical education and health is crucial for physical education teachers*" (Individual interviewee, Individual interview materials 03).

3.1.2 Health beliefs

Health beliefs reflect the long-term and public welfare nature of health promotion work. The effectiveness of health communication may not be immediately apparent, which requires physical education teachers to have firm beliefs. Physical education teachers should have confidence and enthusiasm in their health communication work. The proposal of this ability also reflects the common profit-seeking problem in the field of health communication. Health communication should primarily serve the public interest. However, due to the lack of regulation in this field, many health communication entities prioritize profitability, leading to a certain consumer-induced tendency in the dissemination of health information.

> "*A physical education teacher needs to persevere in their efforts because the effects of health communication may not be immediate. Therefore, they must have faith in the value of the health communication work they are engaged in*" (Individual interviewee, Individual interview materials 04).

> "*There is currently a strong commercial influence in the field of health communication. Many health-related contents disseminated through the internet have some commercial purposes. For example, during the process of health communication, there are instances where products are inadvertently promoted. Therefore, for physical education teachers to effectively engage in health communication, they need to first recognize the underlying public welfare aspect of this matter and possess a certain level of belief in it*" (Individual interviewee, Individual interview materials 02).

3.1.3 Health behavior

Health behavior, as a capability, reflects the current trend in the Chinese health communication field characterized by an "emphasis on theory, neglect of practice." While health education professionals, such as doctors and communication scholars, possess substantial health knowledge, they also engage in sedentary behaviors. The most significant deficiency in the field of Chinese health communication is a communicative agent that not only possesses theoretical knowledge but also serves as a behavioral model. Overemphasizing the transmission of theoretical knowledge can lead to diminishing returns in the effectiveness of health communication in practice. Therefore, physical education teachers themselves also need to maintain healthy behavior in order to become role models for students and effectively ensure that complex health knowledge is put into practice.

> "*When engaging in health communication, we focus on not only slogans and knowledge dissemination but also providing practical examples. For instance, an* [sic] *user called Genghong Liu in Douyin (a social media platform similar as TikTok), who guiding other online users for physical fitness training by live streaming [sic]. During his live streaming, more than 100,000 online users participated in exercise. This type of online physical fitness course embraced by online users was more effective than delivering health education classes or physical education lessons on campus*" (Individual interviewee, Individual interview materials 10).

3.2 Practical competence of health communication

Health communication work possesses a certain level of complexity, requiring physical education teachers to have relatable abilities to coordinate various influential factors to achieve maximum effectiveness.

3.2.1 Language expression competence

Language expression skills were mentioned by all participants. Strong language expression skill is crucial for physical education teachers to effectively delivery health communication work. With the development of information technology, physical education teachers need to consider how to make complex sports and health knowledge more appealing for pupils when using various social media platforms for communication. Excessive specialization in health knowledge can limit the scope of communication. Therefore, overcoming the issue of diverse cultural literacy among the audience during the communication process is essential, and the role of language expression skills becomes particularly significant. Additionally, the ability to interact with the audience during communication places higher demands on language expression skills. This ability also allows them to establish a personal brand and form the basis of a communication community.

> "*I think language expression is necessary because when you want to communicate with pupils, you need to make sure they can understand what you teach. It's essentially a form of language expression. You may have the health knowledge yourself, but when you explain it to pupils, it may be misunderstood by others. So, I believe that art of language matters, namely physical education teachers need to know how to express ourselves*" (Individual interviewee, Individual interview materials 09).

> "*Firstly as a physical education teacher, you definitely need the ability to express yourself through language during teaching, specifically the ability to organize your health knowledge. It's similar to how an expert delivers a lecture in any other field. An expert must possess language expression skill to convey their knowledge in the simplest and most understandable way possible*" (Focus Group Interview Material 01).

3.2.2 Organization and design competence

The organizational design competence suggests that the requirements of diverse communication channels in current health promotion. Whether the health communication among physical education teachers is online or offline, teachers need to possess skills in organizing activities, particularly in coordinating time and space. Given the unevenly developed fitness-related infrastructure across the different regions of China, organizing health communication activities poses challenges for physical education teachers. Additionally, the ability to design effective activities is crucial as it determines the quality of physical education teachers' health communication work and plays a significant role in maintaining the stability of the communication community.

> "*In the context of health communication, one approach is to design practical fitness tests or health-related exercises such as sports injury prevention. Students can absorb health knowledge easily and authentically by participating in health-related activities. Another approach is to implement health-related tests or competitions focusing on enhancing health levels instead of judgment. By receiving feedback from such a test or competition, students can get chance to understand how to enhance and use the health knowledge they learned from physical education teachers. These initiatives require physical education teachers to possess adequate abilities in activity organization and design*" (Focus Group Interview Material 02).

3.2.3 Utilization of social media competence

With the development of technology, the context of health communication has shifted to social media (46). In China, WeChat and Douyin are the primary social media for health-related information dissemination, especially among the young generation. This transformation is mainly driven by the convenience of accessing health information through social media, which has broken the monopoly of traditional media in the dissemination of health information. Therefore, owing to an increasing number of pupils learning health-related knowledge from social media, physical education teachers need to learn the wisdom of social media to support pupils in the new era. Moreover, social media facilitate the formation of virtual communication communities, which potentially provide opportunities for emotional support between teachers and pupils. In turn, it would benefit the health communication for physical education teachers.

> "*There are two key requirements for creating effective health-related videos through social media. First, health-related content expression ability is essential, especially physical education and health knowledge required more authentic experience than other subjects such as math and English [sic]. Second, proficiency in using social media, such as video editing, incorporating* various *materials. These abilities are crucial for conducting health communication in any social media platforms [sic]*" (Individual interviewee, Individual interview materials 13).

3.2.4 Communication content selection and processing competence

The ability to select and process communication content for health promotion requires physical education teachers to choose appropriate content based on their own pupils' needs. Unfortunately, the content of the health communication delivered by physical education teachers will more likely promote public health literacy and health awareness rather than specifically target their own pupils. Thus, the main form of health communication should be refined by considering pupils' needs instead of the general public.

> "*To establish a comprehensive health system, it is essential to focus on specific aspects rather than being too broad. Physical health encompasses a wide range of topics, and there are numerous activities that can be included. For instance, exercises like Tabata involve* various *physical movements, and many other fitness exercises can be incorporated as well. While the exercise for adults might not acceptable for students, so it is important to choose a specific project and refine it to cater to the target audience [sic]. By focusing on a particular activity and ensuring its precision and effectiveness, a more targeted approach can be achieved in health communication*" (Individual interviewee, Individual interview materials 01).

3.2.5 Professional skills

Professional skills in health communication refer to two aspects. First, it pertains to the physical abilities and demonstration skills of physical education teachers themselves. Owing to the specificity of professional identity among physical education teachers, the content of health communication taught by physical education teachers focused on sports and physical training. Second, professional skills in health communication implicates skills in sports injuries, such as injury prevention, the handling of emergency sports injuries, and sports rehabilitation. In conclusion, subject matters are the prominent factors that distinguish the core duty of physical education teachers compared with those of other health communication practitioners.

> "*For a physical education teacher, it is essential to have proficient physical abilities and at least be capable of demonstrating standard movements. Additionally, teach health communication for physical education teachers means teach sports injury prevention and possess knowledge of sports rehabilitation methods [sic]. Therefore, physical education teachers need to acquire these relevant professional skills for effective health communication*" (Individual interviewee, Individual interview materials 11).

3.3 Health communication perception competence

The perception competence of health communication plays a vital role in enhancing the breadth and depth of health communication for physical education teachers within the overall health communication competency model.

3.3.1 Health risk and crisis perception competence

When it comes to health communication, most of the participants mentioned competence related to risk and crisis perception. Participants suggested that the aim of health communication is to enhance the effectiveness of health communication by improving cognition at the behavioral level and seizing specific opportunities for pupils. Theoretically, as for physical education teachers, the purpose of health communication is to influence behavior through cognitive changes, which is similar to the fundamental "knowledge-attitude-behavior (KAP)" model in the field of health communication.

> "*For example, if one of students gets injured during course, the physical education teacher should perceive this challenging situation as an opportunity for teaching pupils about how to deal with such injuries [sic]. It includes not only teaching students how to handle emergency sports injuries in class, but also educating them on injury prevention and self-evaluating physical condition during after-class physical activities. This situation puts physical education teachers' perception ability of health crises to the test*" (Focus Group Interview Material 01).

3.3.2 Communication audience perception competence

The concept of audience perception competence in health communication arose from the call for professional development trends in the competency of physical education teachers in health communication. It also aligns with the capacity for selecting and processing communication content. In other words, health communication content should strive for refinement. The need for refinement stems from the fact that health communication often targets diverse audiences, which vary in terms of age, gender, physical condition, and even job type. For example, office workers are more likely to have sedentary behaviors, whereas physical workers or teenagers are less likely to have sedentary behaviors. Therefore, physical education teachers need to understand the specific needs of their students, whether they are university students, high school students, or primary students.

> "*To achieve greater scientific accuracy and appropriateness, it is necessary to identify different population groups and age ranges, rather than relying on intuition or general statements. There should be established standards to guide the standardization and meticulousness of health knowledge in this regard. I believe it is essential to pay close attention to the standardization and specificity of health knowledge. Even if individuals have some understanding, it cannot be claimed to be 100% accurate. Therefore, targeted health knowledge is more scientific and accurate*" (Individual interviewee, Individual interview materials 04).

4 Discussion

4.1 Interrelationships among all subcompetences in health communication competence

The objective of this study was to examine the health communication competence of physical education teachers through the application of grounded theory. The goal was to provide practical guidance for physical education teachers engaged in health communication and bring a new perspective to research in the field of health communication. Based on the constructed health communication competence for physical education teachers in our study, the health communication competence of physical education teachers can be categorized into three main sub-competences: health communication knowledge and skills, health communication perception competence, and practical competence of health communication.

These subcompetences are interconnected and mutually influential. For instance, physical education teachers must possess sufficient health communication knowledge to develop a strong belief in health communication and maintain a sustainable healthy lifestyle (47). Similar to the health communication competence explored by the objectives of medicine practitioners from Clifford (2013) (19) and Park (21), practical competence in health communication is crucial for teachers to effectively apply their health communication knowledge in practice, guiding their behaviors when engaging in health communication activities.

This becomes particularly relevant in the context of new media, as physical education teachers need to understand how to utilize social media platforms to disseminate appropriate health communication information (32). Furthermore, health communication perception competence plays a vital role. Only when physical education teachers recognize the value of maintaining good health and perceive the risks associated with an unhealthy lifestyle, will they be more motivated to work in health communication. Additionally, they will be inclined to learn more about the specific health communication needs of different individuals and show enthusiasm for participating in or establishing health communication communities.

4.2 Professional identity as opinion leaders and communication agents in physical fitness

Among all health professionals, physical education teachers have different responsibilities than doctors or researchers in the field of communication. While doctors focus on areas such as pharmacology, disease diagnosis and management, clinical skills, and patient assessment, researchers in health communication specialize in competence related to persuasion and negotiation and verbal and non-verbal communication (18). Physical education teachers, on the other hand, have unique responsibilities that require them to learn from doctors and researchers in the field of communication but with a primary emphasis on physical fitness (43, 48–50).

Their professional identity is reflected in categories such as C1 sports health knowledge reserve, C3 health behavior, and C10 professional skills, which highlight their expertise in sports and physical health. Chinese physical education teachers are required to acquire theoretical knowledge of physical health, exercise physiology, and other exercise-related theories. When they become physical education teachers in schools, colleges, or universities, they also need to systematically learn health promotion practices and training. Therefore, physical education teachers are well-positioned to take on leadership roles and act as agents in the realm of health communication, particularly in promoting physical fitness. It is important to note that the specialization of physical education emphasizes the significance of health practices rather than solely delivering health knowledge. This highlights the need to address the current issue of overemphasizing theory and undervaluing practical aspects in health communication. This change cannot be easily achieved by other health professionals, such as doctors or researchers, alone.

Consequently, it is crucial for physical education teachers to actively engage in health communication work and acquire the necessary competence to effectively deliver their expertise and collaborate with other health communication professionals to maximize outcomes. The theoretical model of physical education teachers' health communication competence underscores their professional identity, positioning them as opinion leaders or agents in the field of sports health and fitness communication. They commit to bridging the gap between theory and practice in health communication.

4.3 Physical education teachers' health communication competence guides professionalization

The study on physical education teachers' health communication competences highlights the necessity of acquiring sufficient physical education and health knowledge (51). In today's context of social media, in which anyone can freely voice their opinions, health-related information often becomes distorted for profit-seeking purposes (6). Physical education teachers should take an active role in navigating digital health communication, particularly in promoting physical health. However, the integration of health into physical education is still in its early stages, and it remains voluntary rather than compulsory for physical education teachers.

This implies that they need to make efforts in their professional development journey toward health and commit to behaving like health professionals (52). The professional development path for health communication practice should encompass areas such as sports health knowledge, sports injury prevention, sports rehabilitation, physical training, and fun fitness training (12). Additionally, physical education teachers need to recognize that the audience for health communication extends beyond just students in school (53). Therefore, the professional development path for health communication practice also emphasizes the active understanding of different target groups and acknowledging their specific needs in health promotion. Furthermore, in the context of new media, health communication takes on a different form than with offline contexts. Physical education teachers should embrace new media platforms, such as TikTok, Kuaishou, and WeChat, which are popular online spaces for the public (43, 54, 55). These platforms can serve as tools for health communication and provide opportunities for physical education teachers to learn from other health communication professionals.

Although health communication for physical education teachers predominantly occurs in the digital space, it is important to stress the combination of online and offline approaches (56). Physical education teachers' health communication work should not be limited to knowledge alone but also involve practical implementation. This could include offline activities such as disseminating sports rehabilitation exercises and promoting healthy physical training methods. In conclusion, the theoretical model of physical education teachers' health communication competence suggests a clear professional development path that includes acquiring health-related knowledge, properly utilizing new media platforms, and understanding the specific needs of diverse target audiences.

4.4 The cross-disciplinary integration trend in health communication competence

The model of physical education teachers' health communication competence constructed in our study encompassed a range of subcompetences that extended beyond the field of physical education. This implies that physical education teachers need to step out of their comfort zone and engage in broad learning (57). In today's context, public health needs have become increasingly individualized and complex (58), and relying solely on a single discipline may no longer be sufficient (59). The theoretical model of health communication competence clearly indicates that physical education teachers should seek knowledge and insights from professionals in medicine, communication, and even computer science.

Embracing cross-disciplinary approaches poses a challenge for physical education teachers in their health communication work. However, it also serves as a motivation for them to broaden their horizons and seek professional and emotional support from a larger community of health communication professionals beyond the realm of physical education. In fact, cross-disciplinary collaboration has already demonstrated its significance in the field of medicine (60, 61). For instance, exercise health has made notable contributions to post-operative rehabilitation and the prevention of chronic diseases (62). Similarly, the theories of communication can significantly enhance the effectiveness of physical education teachers in flexibly disseminating health knowledge, whether it be in community settings or on a one-to-one basis. Interpersonal and group communication knowledge from communication studies can prove particularly valuable in this regard. Furthermore, computer science plays a crucial role for physical education teachers, as they primarily use digital spaces for health communication (9). Through big data analysis, they can identify the diverse health needs of online users, enabling them to better understand their target audiences and pinpoint the most critical needs among different audience groups.

In summary, the theoretical model of physical education teachers' health communication competence highlights the importance of embracing cross-disciplinary learning. Physical education teachers not only need to understand their expertise in sports but also expand their knowledge by seeking insights from medicine, communication, and computer science. This approach allows them to effectively address the increasingly individualized and complex public health needs. By broadening their horizons and engaging with a larger community of health communication professionals, physical education teachers can enhance their professional capabilities and provide valuable support beyond the scope of physical education alone.

4.5 Limitations and future research

Although the competences of physical education teachers exhibit social and cultural variations, it is important to acknowledge that significant cultural differences exist among different religions in China (63). However, a notable aspect to acknowledge is the study's sample size, which, although suitable for exploratory research, may not be sufficiently large to comprehensively represent all regions. This limitation poses potential challenges in generalizing the findings to the entire population of physical education teachers across the country or worldwide. To address this limitation and enhance the practicality and scientific validity of the theoretical model, future research endeavors should prioritize expanding the sample size. By including a more diverse and extensive representation of regions, researchers can capture the nuanced variations in cultural and social contexts, making the theoretical model more applicable and applicable across a broader spectrum of other populations or ethnicities.

Furthermore, future research can delve deeper into the various factors influencing the formation process of physical education teachers' health communication competence, building upon the existing foundation. One avenue worth exploring is the role of social media competence among physical education teachers. This entails a detailed examination of the current state of teachers' social media skills and their proficiency in conveying health communication knowledge through digital platforms. The research could involve a nuanced analysis of teachers' social media repertoires, investigating the range of platforms they use and how adeptly they navigate these channels to effectively communicate health-related information. This exploration would not only contribute valuable insights into the proficiency levels of physical education teachers but also provide a deeper understanding of the strategies and approaches they employ to engage with diverse audiences on multiple media platforms.

Moreover, we acknowledge that qualitative research can provide deeper insights into perceptions, attitudes, and beliefs in research on health communication, but our experience has indicated that analyzing qualitative data from semi-structured interviews presents greater challenges than analyzing qualitative data from structured interviews. The transcription of focus group data is particularly challenging due to issues such as voice overlapping and simultaneous speech, which requires approximately 6 h to complete. Additionally, there was a lack of diversity in the conversation because of some individuals dominating it. To enhance data quality, future research should select a location that is noise-free if interviews are to be conducted. To achieve high quality qualitative data, interviewers must be proficient in asking probing questions, possess excellent organizational skills, and be able to guide interviewees toward the research questions politely without causing unwanted topic deviations.

Lastly, it would be valuable for future studies to extend their focus to other professionals involved in health communication, such as doctors, nurses, and health education teachers. Exploring the theoretical model of their health communication competence would provide insights into the unique competences and skills required in their respective fields. This comparative analysis would contribute to a comprehensive understanding of health communication competence across various professional domains.

5 Conclusion

The research formed the constitution dimension of health communication competence of physical education teachers through three-level coding guided by the grounded theory approach. It resulted in three main categories: health knowledge and skill, health communication perception competence, and practical competence of health communication. The health communication knowledge and skills included three subcategories: sports and health knowledge reserve, health belief, and health behavior. Health communication perception competence included health risk and crisis perception competence and communication audience perception competence. The practical competence of health communication included five sub categories: language expression competence, organization and design competence, utilization of new media tools competence, communication content selection and processing competence, and professional skills. The three main categories and 10 subcategories were derived from 30 concepts and 240 labels from individual interviews and focus groups. Finally, through theoretical saturation testing, it was proven that the theoretical model of Chinese physical education teachers' health communication competence has good reliability and validity.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by College of Physical Education and Health, East China Normal University, Shanghai, China. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

LC and YX: conceptualization and writing—original draft preparation. ZY, ZG, and BL: methodology and funding acquisition. LC: software. LC, YX, and MS: formal analysis. LC, YX, and FL: writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1233738/full#supplementary-material

References

1. Høydalsvik TEL. The hidden professionals? An interview study of higher education-based teacher educators professional identity. *Nord Tidssk Utdan Praksis*. (2019) 13:93–113. doi: 10.23865/up.v13.1974

2. Hu D, Liu Z, Zhang H, Jiang C. Changes in physical health-related indexes of Chinese college students before and after Covid-19 lockdown. *Biomed Res Int*. (2022) 2022:1–6. doi: 10.1155/2022/7802492

3. Zhang YA. The model of adolescent sports health communication: theoretical framework, variable relationships, and effect evaluation. *J Chengdu Sport Univ*. (2018) 2:24–30. doi: 10.15942/j.jcsu.2018.02.005

4. Langnes TF, Walseth K. This is what I learned about the body on social media: Pete Students' experiences with body pressure and body positivity. *Sport Educ Soc*. (2023) 28:253–71. doi: 10.1080/13573322.2021.2022642

5. Creswell JW. *Research Design: Qualitative and Quantitative Approaches*. Thousand Oaks, Calif.: Sage Publications (1994).

6. Vercruysse S, De Clercq D, Goossens L, Aelterman N, Haerens L. Development and optimization of an injury prevention intervention for physical education teachers. *Phys Educ Sport Pedagog*. (2017) 22:171–86. doi: 10.1080/17408989.2016.1165192

7. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. (2020) 54:1451–62. doi: 10.1136/bjsports-2020-102955

8. Andrieieva O, Blystiv T, Byshevets N, Moseychuk Y, Balatska L, Liasota T, et al. Assessment of the impact of outdoor activities at leisure facilities on the physical activity of 15-year-old schoolchildren during the Covid-19 pandemic. *J Phys Educ Sport*. (2022) 22:1839–47. doi: 10.7752/jpes.2022.08231

9. Brooks CC, McMullen JM. Using Social Media: One Physical Education Teacher's Experience. *J. Teach. Phys. Educ*. (2020) 39:464–71. doi: 10.1123/jtpe.2020-0005

10. Jones I, Gratton C. *Research Methods for Sports Studies. 2nd ed.* London: Routledge (2010).

11. Zhou J, Xie X, Guo B, Pei R, Pei X, Yang S, et al. Impact of Covid-19 lockdown on physical activity among the Chinese youths: the Covid-19 impact on lifestyle change survey (Coinlics). *Front Public Health*. (2021) 9:592795. doi: 10.3389/fpubh.2021.592795

12. Goodyear V, Armour K. *Young People, Social Media and Health. Routledge Studies in Physical Education and Youth Sport. 1st* ed. London: Taylor & Francis (2019).

13. Coleman CA, Hudson S, Maine LL. Health literacy practices and educational competencies for health professionals: a consensus study. *J Health Commun*. (2013) 18:82–102. doi: 10.1080/10810730.2013.829538

14. Ji X, Zheng S, Cheng C, Cheng L, Cronin L. Development and psychometric evaluation of the Chinese version of the life skills scale for physical education. *Int J Environ Res Public Health*. (2022) 19:5324. doi: 10.3390/ijerph19095324

15. Bulger S, Illg K, Jones E. Achieving alignment in the preparation of Cspap leaders in Pete programs. *J Phys Educ Recreat Dance*. (2017) 88:37–42. doi: 10.1080/07303084.2017.1260982

16. An R, Shen J, Ying B, Tainio M, Andersen ZJ, de Nazelle A. Impact of ambient air pollution on physical activity and sedentary behavior in China: a systematic review. *Environ Res*. (2019) 176:108545. doi: 10.1016/j.envres.2019.108545

17. Sari EF, Novita NM, Siregar SS, Julianti RR, Resza AM. How physical education through Tiktok makes a difference: the use of Tiktok to promote learning activities. *Int J Hum Mov Sports Sci*. (2022) 10:187–92. doi: 10.13189/saj.2022.100208

18. Chiriac H, Eva CF, Thornberg R. Teachers' perspectives on factors influencing the school climate: a constructivist grounded theory case study. *Cogent Educ*. (2023) 10:2245171. doi: 10.1080/2331186X.2023.2245171

19. Clegg JL, Butryn TM. An existential phenomenological examination of parkour and Freerunning. *Qualitat Res Sport Exerc Health*. (2012) 4:320–40. doi: 10.1080/2159676X.2012.693527

20. Edgar T, Gallagher SS, Silk KJ, Cruz TB, Abroms LC, Evans WD, et al. Results from a national survey of health communication master's degree recipients: an exploration of training, placement, satisfaction, and success. *J Health Commun*. (2015) 20:354–66. doi: 10.1080/10810730.2014.978514

21. Park SY, Harrington N, Crosswell L, Parvanta C. Competencies for health communication specialists: survey of health communication educators and practitioners. *J Health Commun*. (2021) 26:1–21. doi: 10.1080/10810730.2021.1925785

22. Østerlie O, Sargent J, Killian C, Garcia-Jaen M, García-Martínez S, Ferriz-Valero A. Flipped learning in physical education: a scoping review. *Eur Phys Educ Rev*. (2023) 29:125–44. doi: 10.1177/1356336X221120939

23. Piussi R, Krupic F, Senorski C, Svantesson E, Sundemo D, Johnson U, et al. Psychological impairments after Acl injury – do we know what we are addressing? Experiences from sports physical therapists. *Scand J Med Sci Sports*. (2021) 31:1508–17. doi: 10.1111/sms.13959

24. Glaser BG, Strauss A. *The Discovery of Grounded Theory: Theories for Qualitative Research*. Mill Valley: Sociology Press (1967).

25. Hyndman BP, Harvey S. Chapter 6: preservice Teachers' perceptions of twitter for health and physical education teacher education--a self-determination theoretical approach. *J Teach Phys Educ*. (2008) 39:472–80. doi: 10.1123/jtpe.2019-0278

26. Gawrisch DP, Andrew K, Richards R, Killian CM. Integrating technology in physical education teacher education: a socialization perspective. *Quest*. (2020) 72:260–77. doi: 10.1080/00336297.2019.1685554

27. Song C, Gong W, Ding C, Yuan F, Zhang Y, Feng G, et al. Physical activity and sedentary behavior among Chinese children aged 6–17 years: a cross-sectional analysis of 2010–2012 China National Nutrition and health survey. *BMC Public Health*. (2019) 19:1–8. doi: 10.1186/s12889-019-7259-2

28. Guo Q, Huang J, Huang L, Wang H. Defining sports health communication: based on the theory of post-social development. *J Shanghai Univ Sport*. (2023) 3:1–11. doi: 10.16099/j.sus.2021.12.30.0002

29. Gambassi BB, Franzoi MH, de Melo J, Prazeres F, de Jesus FA, Costa CPS, et al. Analysis of the quality of videos on exercise training in Youtube during the Covid-19 pandemic: a short communication. *J Exerc Physiol*. (2022) 25:53–9.

30. Jiménez-Parra JF, Belando-Pedreño N, López-Fernández J, García-Vélez AJ, Valero-Valenzuela A. An interdisciplinary educational programme to promote healthy lifestyles and encourage education in values—a rationale and protocol study. *Appl Sci*. (2022) 12:8073. doi: 10.3390/app12168073

31. Templin TJ, Graber KC, Richards KAR. Chapter 9: Will pete survive in the 21st century? *J Teach Phys Educ*. 38:68–74.

32. Wei W, Wei J, Fang W. Application analysis of flipped classroom based on Wechat public platform in basketball physical education teaching. *J Phys Conf Ser*. (2021) 1744:042228. doi: 10.1088/1742-6596/1744/4/042228

33. Glaser BG, Strauss AL. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York: Aldine de Gruyter (1967).

34. Ho JT, See MTA, Tan AJQ, Levett-Jones T, Lau TC, Zhou W, et al. Healthcare professionals' experiences of interprofessional collaboration in patient education: a systematic review. *Patient Educ Couns*. (2023) 116:107965. doi: 10.1016/j.pec.2023.107965

35. Guest G, Bunce A, Johnson L. How many interviews are enough? An experiment with data saturation and variability. *Field Methods*. (2006) 18:59–82. doi: 10.1177/1525822X05279903

36. Corbin CB. Conceptual physical education: a course for the future. *J Sport Health Sci*. (2021) 10:308–22. doi: 10.1016/j.jshs.2020.10.004

37. Holt NL, Tamminen KA. Improving grounded theory research in sport and exercise psychology: further reflections as a response to Mike weed. *Psychol Sport Exerc*. (2010) 11:405–13. doi: 10.1016/j.psychsport.2009.12.002

38. Green K. Physical education teachers in their figurations: a sociological analysis of everyday 'Philosophies'. *Sport Educ Soc*. (2002) 7:65–83. doi: 10.1080/13573320120113585

39. Li J, Tang Z, Gong Z. Does the message frame promote people's willingness to vaccinate when they worry about side effects from the Covid-19 vaccine? Evidence from an online survey experiment in China. *Health Commun*. (2023) 38:1688–96. doi: 10.1080/10410236.2022.2028469

40. Xu Y, Yin Z, Liu H, Sun M, Guo Z, Liu B. Model construction of Chinese preservice physical education teachers' perception of social media: a grounded theory approach. *Int J Environ Res Public Health*. (2023) 20:3886. doi: 10.3390/ijerph20053886

41. Ekberg J-E. What knowledge appears as valid in the subject of physical education and health? A study of the subject on three levels in year 9 in Sweden. *Phys Educ Sport Pedagog*. (2016) 21:249–67. doi: 10.1080/17408989.2014.946006

42. Casey A, Goodyear VA, Armour KM. *Digital Technologies and Learning in Physical Education: Pedagogical Cases. 1st* ed. London: Routledge (2017).

43. Kvale S. The 1,000-page question. *Qual Inq*. (1996) 2:275–84. doi: 10.1177/107780049600200302

44. Johnson J, Daum D, Norris J. I need help! Physical educators transition to distance learning during Covid-19. *Phys Educ*. (2021) 78:119–37. doi: 10.18666/TPE-2021-V78-I2-10866

45. Baker TL. *Doing Social Research*. *2nd ed.* New York: McGraw-Hill Inc (1994).

46. Casey A, Goodyear VA, Armour KM. (Eds.). *Digital Technologies and Learning in Physical Education: Pedagogical Cases (1st ed.)*. London: Routledge (2016). doi: 10.4324/9781315670164

47. De Sousa RAL, Improta-Caria AC, Aras-Júnior R, de Oliveira EM, SociÚ PR, Cassilhas RC. Physical exercise effects on the brain during Covid-19 pandemic: links between mental and cardiovascular health. *Neurol Sci*. (2021) 42:1325–34. doi: 10.1007/s10072-021-05082-9

48. Barker D, Quennerstedt M, Johansson A, Korp P. Physical education teachers and competing obesity discourses: an examination of emerging professional identities. *J Teach Phys Educ*. (2021) 40:642–51. doi: 10.1123/jtpe.2020-0110

49. Flick U. *An Introduction to Qualitative Research*. *4th* ed. London: SAGE Publications Ltd (2009).

50. Li Y, Zhang Y. Conceptual connotation, development status, and future prospects of sports health communication in China. *J Wuhan Instit Phys Educ*. (2022) 8:28–35. doi: 10.15930/j.cnki.wtxb.2022.08.003

51. Gong Y, MacPhail A, Guberman A. Professional learning and development needs of Chinese university-based physical education teacher educators. *Eur J Teach Educ*. (2021) 46:154–70. doi: 10.1080/02619768.2021.1892638

52. Sparkes AC, Smith B. *Qualitative Research Methods in Sport, Exercise and Health: From Process to Product*. Abingdon, VA: Routledge (2014).

53. Hu WN, Li DY, Lam WK, Wang Y, Wong DWC, Cheung JCW. Physical fitness of Chinese primary school students across the coronavirus (Covid-19) outbreak: a retrospective repeated cross-sectional study. *Int J Environ Res Public Health*. (2022) 19:7870. doi: 10.3390/ijerph19137870

54. Rogers EM. The field of health communication today. *Am Behav Sci*. (1994) 38:208–14. doi: 10.1177/0002764294038002003

55. Wallhead TL, Hastie PA, Harvey S, Pill S. Academics' perspectives on the future of sport education. *Phys Educ Sport Pedagog*. (2021) 26:533–48. doi: 10.1080/17408989.2020.1823960

56. O'Neil K, Andrew K, Richards R. Breaking from traditionalism: strategies for the recruitment of physical education teachers. *J Phys Educ Recreat Dance*. (2018) 89:34–41.doi: 10.1080/07303084.2017.1404511

57. Tsuk S, Zach S, Glixman O, Rotstein A, Avieli E, Mimouni-Bloch A. Attitudes toward stimulant medication for treating Adhd among physical education student teachers. *J Phys Educ Sport*. (2023) 23:1325–31. doi: 10.7752/jpes.2023.05162

58. Liu J, Keating XD. Development of the pre-service physical education Teachers' teacher identity scale. *Eur Phys Educ Rev*. (2022) 28:186–204. doi: 10.1177/1356336X211028832

59. Mulhearn SC, Wieck C. Embracing hybridity to expand the public health reach of physical education on secondary school campuses. *J Phys Educ Recreat Dance*. (2023) 94:5–8. doi: 10.1080/07303084.2023.2172115

60. Parris Z, Cale L, Harris J, Casey A. Physical activity for health, Covid-19 and social media. *Movimento*. (2022) 28:e28002. doi: 10.22456/1982-8918.122533

61. Valley JA, Graber KC. Gender-biased communication in physical education. *J Teach Phys Educ*. (2017) 36:498–509. doi: 10.1123/jtpe.2016-0160

62. Teraoka E, Kirk D. Exploring pupils' and physical education teachers' views on the contribution of physical education to health and wellbeing in the affective domain. *Sport Educ Soc*. (2022) 27:935–45. doi: 10.1080/13573322.2021.1940917

63. Imagbe S, Wang B, Liu Y, Androzzi J, Xiangli G, Chen S. Active living education: leveling the playing field for black or African American students. *J Teach Phys Educ*. (2022) 41:204–11. doi: 10.1123/jtpe.2020-0314

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Personality traits and Chinese college students' satisfaction with physical education classes: the mediating role of trait fluency and the moderating role of physical education class difficulty

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Background: This study aims to investigate the impact mechanism of personality traits on physical education satisfaction among college students, validating the mediating effect of trait flow and the moderating effect of physical education difficulty. By analyzing the influence mechanism of personality traits on college students' satisfaction with physical education classes, it helps to explore more channels to enhance satisfaction with physical education classes.

Methods: A questionnaire survey was conducted using the Big Five Personality Scale, the Physical Education Class Satisfaction Scale, the Trait Fluency Scale, and the Physical Education Class Difficulty Scale with 868 public physical education students in 10 universities in Shanghai. Moderated mediation modeling was conducted using Hayes' PROCESS macro.

Results: Personality traits are positively correlated with physical education satisfaction, and the predictive effect is significant ($\beta = 0.786$, $p < 0.001$). This association is mediated by trait fluency (indirect effect: $\beta = 0.797$, $p < 0.001$), accounting for 62.7% of the total effect. Physical education difficulty significantly moderates the predictive effects of personality traits on physical education satisfaction ($\beta = -0.183$, $p < 0.01$) and trait fluency ($\beta = -0.130$, $p < 0.001$). Additionally, physical education difficulty significantly moderates the predictive effect of trait fluency on physical education satisfaction ($\beta = 0.172$, $p < 0.001$).

Conclusion: Personality traits predict physical education satisfaction, with trait fluency playing a mediating role, and physical education difficulty moderates the direct and indirect paths through which personality traits influence physical education satisfaction.

KEYWORDS

personality trait, trait fluency, student satisfaction, personality factors, difficulty and flow experience, moderated mediation

1 Introduction

In China, school physical education, as one of the key tasks of educational modernization (General Office of the CPC Central Committee, 2019), has received significant attention. Over the past decade, various Chinese central government departments have jointly issued as many as 18 working documents related to school physical education (Liu et al., 2023). These documents aim to provide guidance for school physical education and promote physical education programs (Chen and Wang, 2022). The primary objective of school physical education has always been to enhance students' physical fitness (Zhang, 2015). Physical education courses are considered a crucial component of the Chinese education system (Ma, 2020), spanning from primary and secondary schools to universities (Wang, 2012). Due to the impact of COVID-19, physical education programs have been variably affected, leading to a reduction in physical activities among college students (Cha, 2022). In recent years, the physical well-being of Chinese university students has witnessed a persistent decline (Chen et al., 2020; Education, 2021; Yu et al., 2022). As of the year 2020, the proportion of Chinese university students failing to meet the standard of physical fitness stands at 30% (Wu and Ji, 2023). Moreover, there exists a marked indifference toward sports consciousness and interests, coupled with a lack of awareness and capacity for self-health management (Baena-Extremera et al., 2012). Public physical education classes represent the primary bastion for college students' physical exercise and the cultivation of sporting interests (He, 2019), high quality physical education classes can improve students' physical fitness and health (Kavoura et al., 2021). Measuring satisfaction has become a "hot topic" in higher education research. Previous research has demonstrated the importance of satisfaction in physical education classes, which is critical to improving students' physical health, motor skills, mental health, and social competence (White et al., 2021; Correa-Barwick et al., 2022). This is reinforced by the above mentioned physical fitness status of college students, thus there is a great need to explore the current status of college students' satisfaction with physical education classes as well as the direct and indirect factors.

Research has indicated that personality traits have an impact on students' academic satisfaction (Bolliger and Erichsen, 2013; Kim et al., 2013; Shih et al., 2014). Sutin's study found a significant correlation between personality traits and engagement in physical activities, with personality traits either facilitating or hindering such involvement (Sutin et al., 2016). Evaluating personality traits allows for a relatively accurate prediction of students' levels of satisfaction with their academic experiences (Baruth and Cohen, 2023). Personality traits cover a wide range, and having the extroverted quality of cheerfulness and friendliness produces positive emotions after physical activity (Huang et al., 2007; Wichers et al., 2012). Additionally, personality traits that exhibit emotional richness, creativity, conscientiousness, and dutifulness have been confirmed to positively correlate with course satisfaction (Cohen and Baruth, 2017; Kavoura et al., 2021) and significantly predict satisfaction with courses (Baruth and Cohen, 2023). Furthermore, research has shown that traits such as agreeableness and humility positively influence course satisfaction (Baruth and Cohen, 2023), but some studies have yielded conflicting conclusions, finding no significant relationship (Downs, 2019; Kavoura et al., 2021). Taking Baruth's study as an example, it explores the relationship between personality traits and course satisfaction among 108 current university students at Israel (Baruth and Cohen, 2023). However, prior research has not examined the mediating and moderating mechanisms, leaving room for further investigation in this study. Thus far, there has been no direct research investigating the relationship between personality traits and satisfaction with physical education classes, and the underlying potential mediation and moderation mechanisms remain largely unknown. The present study seeks to explore the connection between personality traits and satisfaction with physical education classes, while examining the potential mediating and moderating roles at play.

On the other hand, despite the prevalent use of linear models to explore the relationship between personality and satisfaction, it is imperative to investigate the inconsistencies by employing mediator and moderator variables (Hou et al., 2018). The presence of mediator or moderator variables adds complexity to the relationship, but theoretically provides a more accurate explanation of the observed phenomena. Among these variables, flow experience describes a state in which individuals wholeheartedly immerse themselves in an activity, experiencing a high level of satisfaction and enjoyment (Beck, 1992). Jackson distinguish flow experience into state fluency and trait fluency. State fluency pertains to the psychological state in which individuals experience flow in specific circumstances, whereas trait fluency represents a personality trait, reflecting an individual's capacity to experience flow. Individuals with higher levels of trait fluency are more prone to experiencing flow states (Jackson et al., 1998). Engaging in physical activities can evoke the experience of trait fluency (Kawabata, 2018; Yoon et al., 2020), with each physical activity having the potential to induce trait flow in its unique way (Elkington, 2011). On the one hand, college students' trait fluency in physical education classes influences their satisfaction with these classes (Hu et al., 2008). On the other hand, recent studies have demonstrated that trait fluency plays a mediating role in physical activities (Duan et al., 2022; Lin, 2023; Qiu et al., 2023), with individuals high in trait flow more inclined to persevere in exercise and establish a regular exercise routine (Qu et al., 2017). Therefore, trait fluency may act as a mediating variable connecting personality traits to satisfaction with physical education classes.

Furthermore, research has provided evidence of a significant correlation between course difficulty and satisfaction (Lee and Nuatomue, 2021). In a study investigating factors influencing student satisfaction in British business schools, Sutherland found that increasing levels of academic difficulty negatively impact satisfaction, leading to a decline in overall satisfaction (Sutherland et al., 2019). Another study showed that occupational difficulty significantly affects life satisfaction, and college students' employment difficulty can negatively affect satisfaction (Cheng et al., 2014). Thus, it is evident that course difficulty plays a pivotal role in course satisfaction (Tu, 2007). However, there has been a dearth of research examining course difficulty as a moderating variable to explore its relationship with personality traits and course satisfaction. Consequently, this study aims to investigate the moderating role of course difficulty and analyze its influence on the relationship between personality traits and satisfaction with physical education classes.

Drawing upon the aforementioned literature, we have proposed a theoretical model, as depicted in Figure 1, with the aim of exploring the interplay between personality traits, satisfaction with physical education classes, trait fluency, and physical education difficulty. Our objective is to analyze the mechanisms through which personality traits influence satisfaction with physical education classes and to

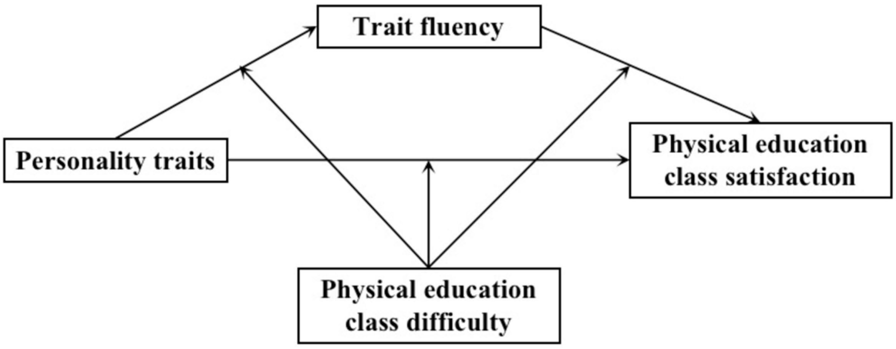

FIGURE 1
Theoretical model.

validate the mediating effect of trait fluency and the moderating effect of physical education difficulty. Specifically, we have put forth the following hypotheses:

> *Hypothesis 1*: There is a positive correlation between personality traits and satisfaction with physical education classes.
>
> *Hypothesis 2*: Trait fluency serves as a mediating mechanism in the relationship between personality traits and satisfaction with physical education classes.
>
> *Hypothesis 3*: The direct and indirect relationships between personality traits and satisfaction with physical education classes are both influenced by the moderating effect of physical education difficulty.

2 Methods

2.1 Participants

In the preliminary pre-survey, 80 questionnaires were distributed to students at Shanghai Normal University. Eighteen questionnaires were excluded due to missing key information and items, resulting in 62 valid questionnaires. In the subsequent main survey, the qualified questionnaires from the pilot survey were used, and a convenient sampling method was employed to survey college students from 10 universities in Shanghai. Both online electronic questionnaires and offline paper-based questionnaires were distributed. Only participants who provided informed consent were allowed to proceed with the survey. The participants in this study were students from various universities and majors, representing diverse academic backgrounds, including computer science, literature, and arts colleges, among others. Inclusion criteria were as follows: (1) undergraduate students, (2) students who had completed a certain number of physical education courses, and (3) students in good physical health. Exclusion criteria were: (1) non-undergraduate students, (2) students with severe health issues or injuries, and (3) students who had not participated in a sufficient number of physical education courses. A total of 957 questionnaires were distributed, with 489 being online surveys and 468 in paper format. Sixty-nine online surveys and twenty paper surveys were excluded due to incomplete data. This resulted in 868 valid questionnaires, with an effective response rate of 90.7%. According to research standards, a sample size between 5 to 10 times the number of items on the questionnaire is acceptable (Fritz and MacKinnon, 2007). In this study, there were a total of 43 items, so a sample size exceeding 215 is adequate. The final sample size for this study was 868, meeting the requirements. The average age of the participants was 19.29 ± 1.26 years, with 33% being male and 67% female. The participation rates of participants from each university were approximately 10%.

2.2 Measurement

2.2.1 Big five personality scale

This study employed the Brief Form of the Chinese Adjective-Based Big Five Personality Inventory (BFFP-CAS-S), devised by Luo and Dai (2018), to assess the Big Five personality traits. The inventory consists of 20 items, encompassing five individual dimensions: extraversion, agreeableness, conscientiousness, neuroticism, and openness. Examples of questions are "I am often afraid," "I feel like I am going to break down when I am under pressure" and "I have quite an imagination." Each item in the scale was rated on a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5). Previous research has substantiated the BFFP-CAS-S to demonstrate sound reliability and validity (Luo et al., 2019). The Cronbach's alpha coefficient for the entire scale was calculated to be 0.86.

2.2.2 Physical education class satisfaction scale

This study employed the Adolescent Physical Exercise Satisfaction Scale, revised by Yang (2016) which is an adaptation of the Satisfaction with Life Scale originally developed by Diener et al. (1985). In this study, the term "physical exercise" was replaced by "physical education class" to form a unidimensional structure consisting of five entries, including: (1) "Most aspects of my physical education class are close to my ideal." (2) "My state during physical education class is very good." (3) "I am satisfied with my physical education class." (4) "So far, I have obtained important things I wanted from physical education class."(5) "If I could go back and choose my physical education class again, I would hardly change anything." Each item in the scale was rated on a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5), with higher scores indicating higher satisfaction with physical education classes. The Cronbach's alpha coefficient for the entire scale was calculated to be 0.90 (See Supplementary material).

2.2.3 Trait fluency scale

This study used Liu's (2010) simplified single-dimension multi-item Trait Fluency Scale to evaluate participants' general inclination to experience flow characteristics. Participants were asked to recall the frequency with which they typically experience each flow-related item during physical education classes. The scale consists of 9 items, corresponding to 9 flow characteristics: 1 = balance between challenge and skill; 2 = integration of action and awareness; 3 = clear goals; 4 = immediate feedback; 5 = concentration; 6 = sense of control; 7 = loss of self-consciousness; 8 = altered sense of time; 9 = autotelic experience. Each item on the scale was rated using a 5-point Likert scale, ranging from "never" (1) to "always" (5). The overall scale demonstrated excellent internal consistency, with a Cronbach's alpha coefficient of 0.90.

2.2.4 Physical education difficulty scale

In this study, the MOOC Difficulty Scale, revised by Zhang (2019), was employed, with the term "MOOC" replaced by "physical education classes," resulting in a unidimensional structure consisting of three items to assess the difficulty level of physical education classes. This scale was used to measure students' evaluation of the difficulty level in physical education classes, including: "I find completing gym class to be difficult," "Completing physical education classes is a challenge for me." and "I find PE very complicated." Each item on the scale was rated using a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5), with higher scores indicating higher difficulty in physical education classes. The Cronbach's alpha coefficient for the entire scale was calculated to be 0.87 (See Supplementary material).

2.3 Procedures

This study illustrates the specific steps and procedures of data collection (Figure 2). Data for the pilot survey and the formal survey were collected from February to March 2020 within university settings using a combination of online and offline methods. Offline data collection was carried out by researchers through on-site surveys at various universities in Shanghai, where they interacted with participants and addressed their inquiries. Online data were collected using the secure online survey platform "Wenjuanxing" (https://www.wjx.cn). Our survey was conducted in an environment of independent completion, without the presence of teachers waiting nearby. We provided the questionnaire link to students and promoted it in the classroom, encouraging them to complete the survey within the specified time. This design was implemented to maximize the autonomy and independence of the participants. Trained researchers administered these measures using scripts and procedural manuals to ensure standardization in the data collection process. Prior to data collection, informed consent forms were distributed to university students, and all students provided their consent for the handling of their relevant data in association with their participation in the study. Students were informed that their participation was entirely voluntary, and they could opt out at any time.

2.4 Statistical analysis

All statistical analyses were conducted using SPSS 23.0 software. Initially, descriptive statistics (i.e., M, SD) were computed for all variables, followed by bivariate correlations among these variables, with $p < 0.05$ (two-tailed) set as the significance level. Moderated mediation analysis was performed using the SPSS-Process 4.1 developed by Hayes. The association between personality traits and satisfaction with physical education classes was mediated by trait flow. Model 4 was employed to examine the mediated relationship between personality traits and satisfaction with physical education classes through trait flow. The moderating effect of physical education class difficulty on the mediation model was tested using Model 59, employing 5,000 bootstrap samples and bias-corrected 95% confidence intervals for bootstrap analysis. All models controlled for covariates such as age, gender, and school.

3 Results

3.1 Descriptive statistics

The results of the descriptive statistical analysis (Table 1) reveal that the mean score for satisfaction with physical education classes is 3.50 ± 0.89, indicating that college students' satisfaction with physical education classes is at a moderately high level.

The demographic characteristics are presented in detail in Table 2. There were no significant differences in university students' satisfaction with physical education courses regarding gender ($p > 0.05$). However, significant differences were observed in terms of grade level ($t = 5.923$, $p < 0.05$) and school ($t = 24.751$, $p < 0.01$). Concerning grade level, sophomore students had a higher mean satisfaction score ($M = 3.583$), while senior students had a lower mean score (M = 3.195). Regarding schools, satisfaction with physical education courses was higher at Shanghai Normal University ($M = 3.923$) and lower at Shanghai Sports University ($M = 3.325$).

3.2 Correlation matrix of physical education class satisfaction with other variables

The results of correlation analysis (see Table 3) indicate that personality traits are significantly positively correlated with satisfaction with physical education classes and trait fluency. Moreover, trait fluency is significantly positively correlated with satisfaction with physical education classes. On the other hand, there is a significant negative correlation between the difficulty of physical education classes and both satisfaction with physical education classes and trait fluency. Thus, Hypothesis 1 is supported.

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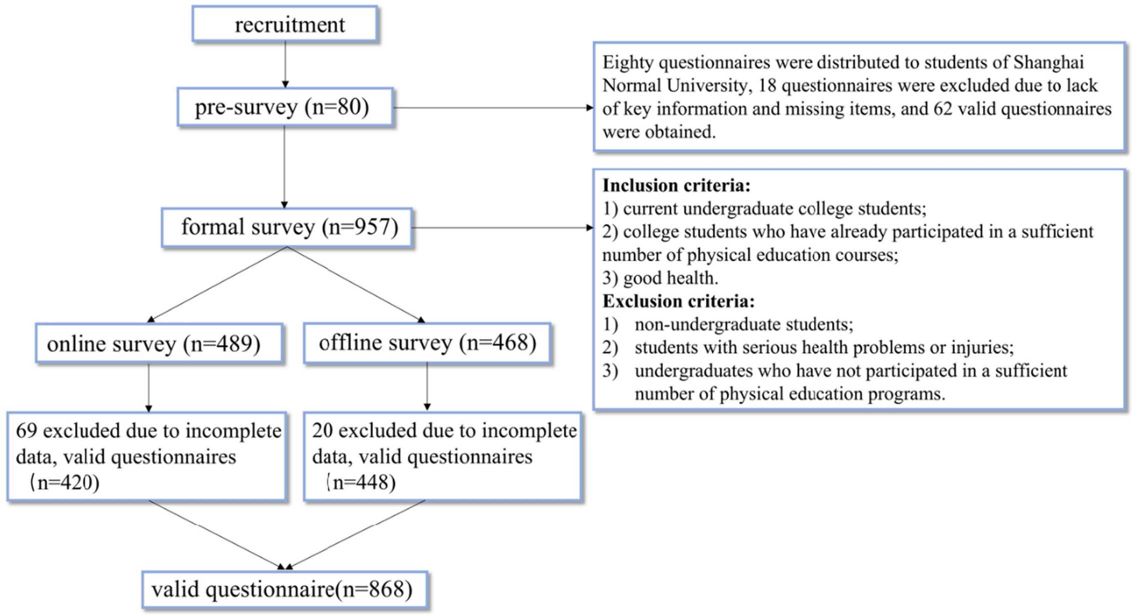

FIGURE 2
Data collection flowchart.

TABLE 1 Descriptive statistics of college students' satisfaction with physical education classes (overall score situation).

	N	Minimum value	Maximum values	*M*	*SD*
PE satisfaction	868	1	5	3.507	0.893

PE, physical education.

3.3 Testing for mediation effect

After controlling for gender, age, and school as covariates, the mediating effect of trait fluency in the relationship between personality traits and satisfaction with physical education classes was examined. The results are presented in Table 4. It was found that personality traits significantly predicted satisfaction with physical education classes ($\beta = 0.786$, $t = 16.409$, $p < 0.001$). Furthermore, even after introducing trait fluency as a mediating variable, the direct predictive effect of personality traits on satisfaction with physical education classes remained significant ($\beta = 0.293$, $t = 5.564$, $p < 0.001$). Additionally, the predictive effect of personality traits on satisfaction with physical education classes remained significant under the mediation of trait fluency ($\beta = 0.797$, $t = 21.845$, $p < 0.001$), and trait fluency also significantly predicted satisfaction with physical education classes ($\beta = 0.618$, $t = 15.677$, $p < 0.001$).

Subsequently, based on bootstrap confidence intervals, the direct effects of personality traits on physical education class satisfaction, as well as the upper and lower bounds of the mediating effect of trait fluency, were found to be non-inclusive of 0 (Table 5). The direct effect (0.293) accounted for 37.301% of the total effect (0.768), while the mediating effect (0.493) accounted for 62.712% of the total effect (0.768). These findings indicate that personality traits not only have a direct predictive effect on physical education class satisfaction but also exert their predictive influence on it through the mediating role of trait fluency. Therefore, Hypothesis 2 is supported.

3.4 Tests for moderated mediation effects

After controlling for covariates such as gender, age, and school, we examined the moderating effect of physical education class difficulty on the direct and indirect relationship between personality traits and physical education class satisfaction. The results revealed (Tables 6, 7) significant predictive effects of the interaction term between personality traits and physical education class difficulty on physical education class satisfaction ($\beta = -0.183$, $t = -3.849$, $p < 0.01$), as well as on trait fluency ($\beta = -0.130$, $t = -3.801$, $p < 0.001$). Additionally, the interaction term between trait fluency and physical education class difficulty significantly predicted physical education class satisfaction ($\beta = 0.172$, $t = 5.201$, $p < 0.001$). These findings suggest that physical education class difficulty not only moderates the direct prediction of personality traits on physical education class satisfaction but also moderates the prediction of personality traits on trait fluency and trait fluency on physical education class satisfaction. Therefore, Hypothesis 3 is supported.

To reveal specific moderating effects, participants were divided into "low group" and "high group" based on $M \pm 1SD$, and further subjected to simple slope analysis (see Figures 2–4). From Figure 2, it can be observed that for participants with lower levels of physical education class difficulty ($M - 1SD$), personality traits significantly positively predicted trait fluency ($\beta simple = 0.91$, $p < 0.001$). Similarly, for participants with higher levels of physical education class difficulty ($M + 1SD$), personality traits also positively predicted trait fluency ($\beta simple = 0.66$, $p < 0.001$), but the magnitude of this prediction was relatively smaller. This suggests that with the increase in physical

TABLE 2 Analysis of differences in satisfaction across demographic variables ($N = 868$).

Variant		Number	*M*	*SD*	*t/F*	*p*
Gender	Male	283	3.444	0.928	−1.453	0.146
	Female	585	3.538	0.875		
Grade	Freshman	331	3.561	0.881	5.923	0.001
	Sophomore	345	3.583	0.899		
	Junior	113	3.336	0.891		
	Senior	79	3.195	0.838		
School	1. Fudan University	81	3.632	0.846	24.751	0.000
	2. Shanghai Jiao Tong University	85	3.612	0.806		
	3. East China Normal University	95	3.579	0.755		
	4. Donghua University	79	3.635	0.688		
	5. Shanghai University	97	3.658	0.902		
	6. Shanghai Normal University	80	3.923	0.893		
	7. Shanghai University of Traditional Chinese Medicine	97	3.773	0.785		
	8. Shanghai University of Engineering and Technology	87	3.554	0.902		
	9. Shanghai University of Applied Sciences	87	2.368	0.477		
	10. Shanghai Sports Institute	80	3.325	0.852		

TABLE 3 Analysis of relevant results ($N = 868$).

Variant	*M*	*SD*	1	2	3	4
1. Personality traits	3.312	0.561	1			
2. PE satisfaction	3.507	0.893	0.517**	1		
3. Trait fluency	3.318	0.746	0.620**	0.642**	1	
4. PE difficulty	2.478	0.989	0.126**	0.167**	0.075**	1

**At the 0.01 level (two-tailed), the correlation was significant.

education class difficulty, the predictive effect of personality traits on trait fluency gradually diminishes.

From Figure 3, it can be observed that for participants with lower levels of physical education class difficulty (M-1SD), personality traits significantly positively predicted physical education class satisfaction ($\beta simple = 0.54$, $p < 0.001$). Similarly, for participants with higher levels of physical education class difficulty (M + 1SD), personality traits also positively predicted physical education class satisfaction ($\beta simple = 0.18$, $p < 0.001$), but the magnitude of this prediction was relatively smaller. This suggests that with the increase in physical education class difficulty, the predictive effect of personality traits on physical education class satisfaction gradually diminishes.

Based on Figure 5, it is evident that for participants with lower levels of physical education class difficulty (M-1SD), trait fluency positively predicted physical education class satisfaction ($\beta simple = 0.40$, $p < 0.001$), but the predictive effect was relatively smaller. Conversely, for participants with higher levels of physical education class difficulty (M + 1SD), trait fluency also positively predicted physical education class satisfaction, and the predictive effect was relatively larger ($\beta simple = 0.75$, $p < 0.001$). This suggests that with the increase in physical education class difficulty, the predictive effect of trait fluency on physical education class satisfaction shows a gradual upward trend.

4 Discussion

This study conducted an investigation on college students' participation in public physical education classes, aiming to explore the mediating role of trait fluency and the moderating effect of physical education class difficulty in the relationship between personality traits and physical education class satisfaction. The research findings have provided valuable data and contributed to a deeper understanding of the factors related to physical education class satisfaction with respect to personality traits.

The importance of personality traits as influential factors on course satisfaction has been empirically supported (Bolliger and Erichsen, 2013; Shih et al., 2014). In this study, we further refined course satisfaction to specifically focus on physical education class satisfaction, and the results revealed a positive correlation between personality traits and physical education class satisfaction. Moreover, personality traits were found to have a predictive effect on physical education class satisfaction, consistent with prior research such as the studies conducted by Baruth and Cohen (2023) and Shih et al. (2014), which demonstrated that personality traits can predict satisfaction in online learning courses among college students. Numerous studies have demonstrated that personality traits are significant factors influencing physical activities (Burgos-Garrido et al., 2011; Wilson

TABLE 4 Mediation model test for trait fluency ($N = 868$).

Regression equation		Goodness of fit index			Significance of the coefficient		
Outcome variable	Predictor variable	R	R^2	F	β	t	p
Satisfaction	Gender	0.527	0.277	82.870	−0.039	−0.707	0.480
	Grade				−0.042	−1.480	0.139
	School				−0.027	−2.809	0.005
	Personality trait				0.786	16.409	0.000
Trait fluency	Gender	0.630	0.397	142.043	−0.077	−1.813	0.070
	Grade				−0.030	−1.386	0.166
	School				−0.024	−3.244	0.001
	Personality trait				0.797	21.845	0.000
Satisfaction	Gender	0.662	0.438	134.210	0.008	0.166	0.868
	Grade				−0.024	−0.936	0.349
	School				−0.012	−1.443	0.150
	Personality trait				0.293	5.564	0.000
	Trait fluency				0.618	15.677	0.000

TABLE 5 Breakdown of total, direct, and mediating effects.

	Effect value	Boot standard error	Boot ULCI	Boot LLCI	Relative effect value
Total effect	0.786	0.048	0.692	0.880	/
Direct effect	0.293	0.053	0.190	0.396	37.301%
Mediating effects	0.493	0.044	0.411	0.581	62.712%

ULCI, upper level of confidence interval; LLCI, lower level of confidence.

et al., 2016; Engels et al., 2022; Piepiora et al., 2023), and they can serve as indicators for predicting sports engagement (Smith et al., 2017) and performance (Piepiora, 2021). The research by Piepiora corroborates the relationship between sports and personality traits: as the duration of physical activities increases, so do the scores on the Big Five personality traits (Piepiora et al., 2022). Personality traits play a role in determining athletic success, interpersonal relationships, and psychological well-being (Piepiora, 2020). Furthermore, distinct sports may exhibit specific associations with particular personality traits, with team sports showing higher scores on Big Five personality indicators (Piepiora, 2021). These findings underscore the pivotal role of personality traits in satisfaction with physical education courses and lend support to the outcomes of this study.

Furthermore, our study indicates a positive correlation between trait fluency and physical education class satisfaction, with trait fluency mediating the relationship between personality traits and physical education class satisfaction. Personality traits significantly predict physical education class satisfaction through the mediation of trait fluency, and trait fluency itself also significantly predicts physical education class satisfaction, confirming its importance as a determinant of class satisfaction (Hu et al., 2008). Consistent with the theory of flow, which posits that the experience of flow is driven by intrinsic motivation (Mandigo and Holt, 2006), individuals engaged in activities driven by intrinsic motivation tend to demonstrate greater engagement and satisfaction (Jackson, 1992). Intrinsic motivation has been found to be positively associated with participation in physical activities (Li, 2010), and extensive research has highlighted trait fluency as an essential factor in physical activities (Yu and Hu, 2009; Gao, 2010; Qu et al., 2017). Moreover, intrinsic motivation is enhanced with an increase in the frequency of trait fluency experiences (Wang et al., 2011). Based on these analyses, our study posits that trait fluency can stimulate intrinsic motivation in physical activities, leading to a greater tendency for highly trait fluent college students to persist in exercising during physical education classes, resulting in higher levels of class satisfaction.

Our research findings confirm the moderating role of physical education class difficulty in the direct and indirect associations between personality traits and physical education class satisfaction. Specifically, we observed a significant negative correlation between physical education class difficulty and class satisfaction, consistent with the findings of Lee and Nuatomue (2021) and Sutherland et al. (2019). The moderated mediation test showed that as the level of physical education class difficulty increased, the predictive effect of personality traits on trait fluency and physical education class satisfaction decreased significantly, while the predictive effect of trait fluency on physical education class satisfaction increased significantly. This indicates that as the level of physical education class difficulty increases, personality traits are relatively more likely to enhance their physical education class satisfaction through trait fluency. The reason behind this could be that certain college students' trait fluency does not align well with the difficulty level of public physical education classes, making it more likely for them to disengage when faced with higher levels of difficulty. On the other hand, individual students with higher trait fluency may find

TABLE 6 Mediation model test with moderation ($N = 868$).

Regression equation		Goodness of fit index			Significance of the coefficient		
Outcome variable	Predictor variable	R	R^2	F	β	t	p
TF	Gender	0.644	0.414	101.556	−0.083	−1.965	0.050
	Grade				−0.022	−1.001	0.317
	School				−0.025	−3.426	0.001
	PT				0.786	21.635	0.000
	PE difficulty				−0.048	−2.386	0.017
	PT × PE difficulty				−0.130	−3.801	0.000
Satisfaction	Gender	0.692	0.479	98.582	0.017	0.361	0.718
	Grade				−0.018	−0.738	0.461
	School				−0.017	−2.029	0.043
	PT				0.361	6.999	0.000
	Trait fluency				0.574	14.857	0.000
	PE difficulty				−0.144	−6.218	0.000
	PT × PE difficulty				−0.183	−3.849	0.000
	TF × PE difficulty				0.172	5.201	0.000

PT, personality trait; TF, trait fluency.

TABLE 7 Moderated mediating effects of difficulty in physical education classes across levels of moderation.

	PE difficulty	Effect value	Boot standard error	Boot ULCI	Boot LLCI
MME	1.48 (M-1SD)	0.370	0.070	0.505	0.232
	2.47 (M)	0.451	0.043	0.537	0.368
	3.46 (M + 1SD)	0.490	0.070	0.623	0.345

MME, moderated mediation effect; Boot standard error refers to the standard error of the indirect effect estimated by the bias-corrected percentile Bootstrap method, Boot CI upper and lower bounds refer to the upper and lower bounds of the 95% confidence interval; all values are retained to two decimal places based on rounding.

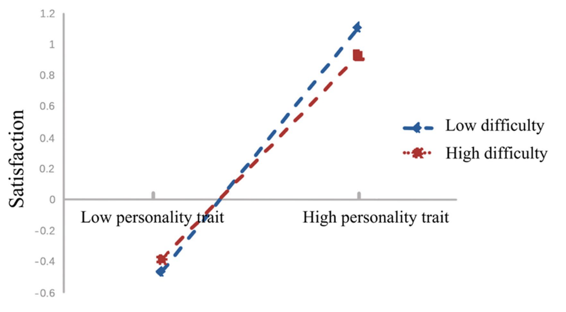

FIGURE 3
Moderating role of physical education class difficulty in the relationship between personality traits and trait fluency.

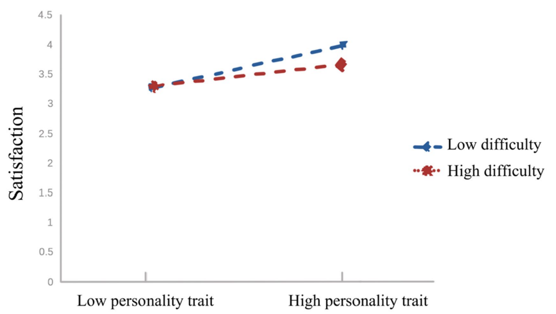

FIGURE 4
Moderating role of physical education class difficulty in the relationship between personality traits and physical education class satisfaction.

it easier to experience flow states and match the higher difficulty levels. Similar research seems to support this notion, as demonstrated by Wang et al. (2020), where learning difficulty, as a moderating variable, significantly predicted classroom negativity. Both low and high learning difficulty levels resulted in negative outcomes (Daschmann et al., 2014; Cui et al., 2017), but higher learning difficulty was more likely to induce negative emotions (Tanaka and Murayama, 2014). Therefore, only an appropriate level of difficulty in physical education can promote students to achieve trait fluency and enhance satisfaction in physical education.

This study has certain limitations. Firstly, it adopts a cross-sectional design, which precludes the establishment of causal relationships. For instance, conducting experimental interventions targeting trait fluency and physical education difficulty, altering teaching methods and content, could be employed to ascertain whether improvements in student satisfaction occur. Furthermore, monitoring changes in university students' physical education satisfaction over time could provide validation of the mediating and moderating effects. Future research should employ longitudinal or experimental designs to confirm the causal hypotheses proposed in this study. Secondly, the limited representativeness of the sample, which is

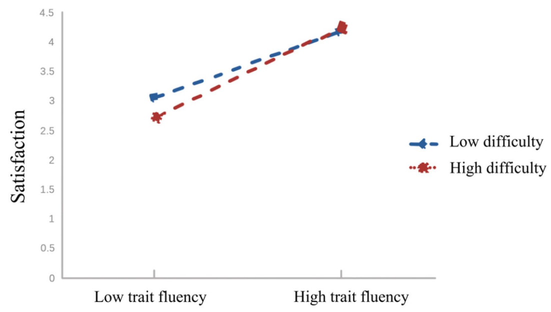

FIGURE 5
Moderating role of physical education class difficulty in the relationship between trait fluency and physical education class satisfaction.

predominantly concentrated in the Shanghai region, hinders the generalizability of the findings. Subsequent research should broaden the sample size to investigate university students from diverse regions and cultural backgrounds, aiming to explore and validate the proposed model. Third, this study exhibits a significant gender imbalance, and future research should consider a more balanced distribution of sexes. Fourth, due to the impact of the COVID-19 pandemic, data collection occurred through a mixed online and offline approach. Despite measures taken to ensure quality and reliability, potential biases cannot be entirely ruled out. Subsequent research should contemplate data collection in more typical circumstances. Fifth, we did not analyze the impact of the five dimensions of personality traits on satisfaction with physical education courses. Subsequent studies delving into the influence of each dimension on satisfaction may offer more insights.

The results of this study can offer guidance to educational policymakers concerning how to enhance university physical education programs to improve student satisfaction. By highlighting the significance of trait flow and the difficulty of physical education courses, school administrators can utilize these findings to enhance their institution's physical education programs and better cater to student needs. Additionally, these results provide a research framework for other researchers to further investigate practical approaches for personalized improvements in physical education courses.

5 Conclusion

This study examines the influence of personality traits on physical education satisfaction among Chinese university students and reveals the mediating role of trait fluency in this relationship. Furthermore, it investigates the moderating effect of physical education difficulty in the pathway between personality traits and physical education satisfaction. For college students, trait fluency enhances physical education satisfaction, and an appropriate level of physical education difficulty serves to further elevate satisfaction by moderating trait fluency. This study provides a theoretical foundation for improving physical education programs and enhancing student satisfaction in these courses.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of Shandong University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ZC: Conceptualization, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. YT: Investigation, Supervision, Writing – review & editing. ML: Formal analysis, Writing – review & editing. SY: Conceptualization, Funding acquisition, Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1270089/full#supplementary-material

References

Baena-Extremera, A., Granero-Gallegos, A., Bracho, C.-A., and Pérez-Quero, F. J. (2012). Spanish version of the sport satisfaction instrument (SSI) adapted to physical education. *Revista de psicodidáctica* 17, 377–395. doi: 10.1387/Rev.Psicodidact.4037

Baruth, O., and Cohen, A. (2023). Personality and satisfaction with online courses: the relation between the big five personality traits and satisfaction with online learning activities. *Educ. Inf. Technol.* 28, 879–904. doi: 10.1007/s10639-022-11199-x

Beck, L. A. (1992). Flow - the psychology of optima experience - CSIKSZENTMIHALYI. *M. J. Leisure Res.* 24, 93–94. doi: 10.1080/00222216.1992.11969876

Bolliger, D. U., and Erichsen, E. A. (2013). Student satisfaction with blended and online courses based on personality type / Niveau de satisfaction des étudiants dans les cours hybrides et en ligne basé Sur le type de personnalité. *Can. J. Learn. Technol.* 39:1.

Burgos-Garrido, E., Gurpegui, M., and Jurado, D. (2011). Personality traits and adherence to physical activity in patients attending a primary health Centre. *Int. J. Clin. Health Psychol.* 11, 539–547.

Cha, Y. (2022). A study on the strategies of school sports to promote the healthy development of adolescents under normalized epidemic prevention and control. *J. Phys. Educ.* 29, 91–95. doi: 10.16237/j.cnki.cn44-1404/g8.2022.05.006

Chen, X., Cui, J., Zhang, Y., and Peng, W. (2020). The association between BMI and health-related physical fitness among Chinese college students: a cross-sectional study. *BMC Public Health* 20:444. doi: 10.1186/s12889-020-08517-8

Chen, Y., and Wang, X. (2022). Characteristics, problems and countermeasures of the school sports policy system. *Sports Cult. Guide* 4, 96–102.

Cheng, H., Zhuang, M., Liu, L., and Hao, X. (2014). A survey on the status of college Freshmen's professional identity, difficulty in career decision making and life satisfaction--taking the case of freshmen of a major in a university. *Educ. Res. Month.* 2, 85–89. doi: 10.16477/j.cnki.issn1674-2311.2014.02.008

Cohen, A., and Baruth, O. (2017). Personality, learning, and satisfaction in fully online academic courses. *Comput. Hum. Behav.* 72, 1–12. doi: 10.1016/j.chb.2017.02.030

Correa-Barwick, G. S., Carrasco-Poyatos, M., and Molina-Fernandez, J. D. (2022). Emotional intelligence and satisfaction with life in schoolchildren during times of pandemic. *Espiral-Cuadernos Del Profesorado* 15, 57–70. doi: 10.25115/ecp.v15i31.8209

Cui, G., Yao, M., and Zhang, X. (2017). The dampening effects of perceived teacher enthusiasm on class-related boredom: the mediating role of perceived autonomy support and task value. *Front. Psychol.* 8:400. doi: 10.3389/fpsyg.2017.00400

Daschmann, E. C., Goetz, T., and Stupnisky, R. H. (2014). Exploring the antecedents of boredom: do teachers know why students are bored? *Teach. Teach. Educ.* 39, 22–30. doi: 10.1016/j.tate.2013.11.009

Diener, E., Emmons, R. A., Larsen, R. J., and Griffin, S. (1985). The satisfaction with life scale. *J. Pers. Assess.* 49, 71–75. doi: 10.1207/s15327752jpa4901_13

Downs, G.H. (2019). An exploration of the relationship between personality type and satisfaction with online learning environments. Portland: 2019 Portland International Conference on Management of Engineering and Technology.

Duan, X., Wang, X., Li, X., Li, S., Zhong, Y., and Bu, T. (2022). Effect of mass sports activity on prosocial behavior: a sequential mediation model of flow trait and subjective wellbeing. *Front. Public Health* 10:458. doi: 10.3389/fpubh.2022.960870

Education, M. O. (2021). Eighth National Student Physical Fitness and health survey results released. *Chin. J. School Health* 42, 1281–1282. doi: 10.16835/j.cnki.1000-9817.2021.09.001

Elkington, S. (2011). What it is to take the flow of leisure seriously. *Leisure* 35, 253–282. doi: 10.1080/14927713.2011.614838

Engels, E. S., Reimers, A. K., Pickel, M., and Freund, P. A. (2022). Personality traits moderate the relationships between psychological needs and enjoyment of physical activity. *Psychol. Sport Exerc.* 61:102197. doi: 10.1016/j.psychsport.2022.102197

Fritz, M. S., and MacKinnon, D. P. (2007). Required sample size to detect the mediated effect. *Psychol. Sci.* 18, 233–239. doi: 10.1111/j.1467-9280.2007.01882.x

Gao, F. (2010). *A study of the structure of fluency states in exercise and their predisposing factors*. [master's thesis], [Beijing]: Beijing Sports University.

General Office of the CPC Central Committee (2019). Issuance of the implementation plan for accelerating the modernization of Education (2018-2022). *Peoples Educ.* 5, 11–13.

He, B. (2019). A comparative study of public physical Education programs in China and abroad. *J. Guangzhou Sport Univ.* 39, 115–118. doi: 10.13830/j.cnki.cn44-1129/g8.2019.02.031

Hou, J., Fan, N., Qin, H., and Fang, X. (2018). The influence of adolescents' big five personality on internet addiction: the mediating role of family functioning. *Psychol. Explor.* 38, 279–288.

Hu, J., Jin, X., and Wang, J. (2008). Exploring college Students' satisfaction with physical Education course selection based on fluency experience theory. *J. Phys. Educ.* 8, 68–71. doi: 10.16237/j.cnki.cn44-1404/g8.2008.08.020

Huang, C.-H., Lee, L.-Y., and Chang, M.-L. (2007). The influences of personality and motivation on exercise participation and quality of life. *Soc. Behav. Pers.* 35, 1189–1210. doi: 10.2224/sbp.2007.35.9.1189

Jackson, S. A. (1992). Athletes in flow: a qualitative investigation of flow states in elite figure skaters. *J. Appl. Sport Psychol.* 4, 161–180. doi: 10.1080/10413209208406459

Jackson, S. A., Ford, S. K., Kimiecik, J. C., and Marsh, H. W. (1998). Psychological correlates of flow in sport. *J. Sport Exerc. Psychol.* 20, 358–378. doi: 10.1123/jsep.20.4.358

Kavoura, A., Havlovic, S. J., and Totskaya, N. (2021). "Exploring the relationship of the big five personality traits with student satisfaction with synchronous online academic learning: the case of Covid-19-induced changes" in *Springer proceedings in business and economics* (Switzerland: Springer International Publishing AG), 87–94.

Kawabata, M. (2018). Facilitating flow experience in physical education settings. *Psychol. Sport Exerc.* 38, 28–38. doi: 10.1016/j.psychsport.2018.05.006

Kim, J., Lee, A., and Ryu, H. (2013). Personality and its effects on learning performance: design guidelines for an adaptive e-learning system based on a user model. *Int. J. Ind. Ergon.* 43, 450–461. doi: 10.1016/j.ergon.2013.03.001

Lee, S. J., and Nuatomue, J. N. (2021). Students' perceived difficulty and satisfaction in face-to-face vs. online sections of a technology-intensive course. *Int. J. Dist. Educ. Technol.* 19, 1–13. doi: 10.4018/ijdet.2021070101

Li, L. (2010). *A study of volleyball participation motivation and exercise adherence among college students in general colleges and universities in Fuzhou City, China*. [master's thesis], [Fuzhou (FJ)]: Fujian Normal University.

Lin, P. (2023). The relationship between trait mindfulness and well-being in college students: the serial mediation role of flow experience and sports participation. *Psychol. Res. Behav. Manag.* 16, 2071–2083. doi: 10.2147/prbm.S414890

Liu, W. (2010). Revision of the Chinese versions of the simplified state fluency inventory and the simplified trait fluency inventory. *China Sport Sci.* 30, 64–70. doi: 10.16469/j.css.2010.12.012

Liu, H., Sun, Q., and Zhang, Y. (2023). Research on the system design and reform path of school sports work in China--a comparative analysis based on 10 years of relevant documents on school sports in China and the United States. *J. Capital Univ. Phys. Educ. Sports* 35, 125–139. doi: 10.14036/j.cnki.cn11-4513.2023.02.002

Luo, J., and Dai, X. (2018). Preliminary development of the Chinese adjective big five personality inventory IV: development of the short form version. *Chin. J. Clin. Psych.* 26, 642–646. doi: 10.16128/j.cnki.1005-3611.2018.04.003

Luo, J., Liu, Z., Jian, S., and Wang, M. (2019). The Chinese adjectives big five personality inventory short form version in a Group of Elementary School Teachers. *Chin. J. Clin. Psych.* 27, 534–538. doi: 10.16128/j.cnki.1005-3611.2019.03.022

Ma, D. (2020). Embodied moral Education: a theoretical perspective on the implementation of the fundamental task of "establishing moral Education for people" in school sports. *J. Phys. Educ.* 27, 1–6. doi: 10.16237/j.cnki.cn44-1404/g8.20200604.005

Mandigo, J. L., and Holt, N. L. (2006). Elementary Students' accounts of optimal challenge in physical Education. *Phys. Educ.* 63:170.

Piepiora, P. (2020). A review of personality research in sport. *Pedag. Psychol. Sport* 6, 64–83. doi: 10.12775/PPS.2020.06.04.007

Piepiora, P. (2021). Assessment of personality traits influencing the performance of men in team sports in terms of the big five. *Front. Psychol.* 12:724. doi: 10.3389/fpsyg.2021.679724

Piepiora, P., Baginska, J., Witkowski, K., Nakonieczna, J., and Piepiora, Z. (2023). Comparison of personality differences of polish mountaineers. *Front. Psychol.* 14:238. doi: 10.3389/fpsyg.2023.1120238

Piepiora, P., Piepiora, Z., and Baginska, J. (2022). Personality and sport experience of 20-29-year-old polish male professional athletes. *Front. Psychol.* 13:804. doi: 10.3389/fpsyg.2022.854804

Qiu, F., Zhu, X., and Zhang, X. (2023). The effect of deep leisure on leisure loyalty among older taijiquan participants: the chain mediating role of fluency experience and leisure satisfaction. *J. Wuhan Sports Univ.* 57, 67–73+100. doi: 10.15930/j.cnki.wtxb.2023.02.011

Qu, H., Yao, J., and Shi, J. (2017). A study of the relationship between physical activity adherence, exercise addiction, and trait fluency. *J. Shenyang Sport Univ.* 36, 77–83.

Shih, H.-F., Chen, S.-H.E., Chen, S.-C., and Wey, S.-C. (2014). "The relationship among tertiary level EFL Students' personality, online learning motivation and online learning satisfaction", in: 13th International Educational Technology Conference, 1152–1160.

Smith, G., Williams, L., O'Donnell, C., and McKechnie, J. (2017). The influence of social-cognitive constructs and personality traits on physical activity in healthy adults. *Int. J. Sport Exerc. Psychol.* 15, 540–555. doi: 10.1080/1612197X.2016.1142459

Sutherland, D., Warwick, P., and Anderson, J. (2019). What factors influence student satisfaction with module quality? A comparative analysis in a UK business school context. *Int. J. Manage. Educ.* 17:100312. doi: 10.1016/j.ijme.2019.100312

Sutin, A. R., Stephan, Y., Luchetti, M., Artese, A., Oshio, A., and Terracciano, A. (2016). The five-factor model of personality and physical inactivity: a meta-analysis of 16 samples. *J. Res. Pers.* 63, 22–28. doi: 10.1016/j.jrp.2016.05.001

Tanaka, A., and Murayama, K. (2014). Within-person analyses of situational interest and boredom: interactions between task-specific perceptions and achievement goals. *J. Educ. Psychol.* 106, 1122–1134. doi: 10.1037/a0036659

Tu, X. (2007). An empirical study on the influencing factors of employment satisfaction of university graduates. *Higher Educ. Exp.* 2, 117–119.

Wang, S. (2012). *Research on school physical Education curriculum system*. [PhD's thesis] Shijiazhuang (HB): Hebei Normal University.

Wang, C., Hu, Y., Zhang, X., Wang, J., Cui, G., and Cui, G. (2020). Stability of the mitigating effect of Students' perceived teacher enthusiasm on class-related boredom: moderating role of boredom proneness and perceived task difficulty. *Int. J. Environ. Res. Public Health* 17:2645. doi: 10.3390/ijerph17082645

Wang, Z., Zhou, Y., and Liu, X. (2011). A path analysis of fluency experiences, intra/external motivation, math anxiety, and math achievement. *J. Psychol. Sci.* 34, 1372–1378. doi: 10.16719/j.cnki.1671-6981.2011.06.001

White, R. L., Bennie, A., Vasconcellos, D., Cinelli, R., Hilland, T., Owen, K. B., et al. (2021). Self-determination theory in physical education: a systematic review of qualitative studies. *Teach. Teach. Educ.* 99:103247. doi: 10.1016/j.tate.2020.103247

Wichers, M., Peeters, F., Rutten, B. P. F., Jacobs, N., Derom, C., Thiery, E., et al. (2012). A time-lagged momentary assessment study on daily life physical activity and affect. *Health Psychol.* 31, 135–144. doi: 10.1037/a0025688

Wilson, K. E., Das, B. M., Evans, E. M., and Dishman, R. K. (2016). Structural equation modeling supports a moderating role of personality in the relationship between physical activity and mental health in college women. *J. Phys. Act. Health* 13, 67–78. doi: 10.1123/jpah.2014-0455

Wu, B., and Ji, L. (2023). Effects of a Chinese healthy physical Education program model on college Students' physical Education learning effectiveness. *J. Phys. Educ.* 30, 106–112. doi: 10.16237/j.cnki.cn44-1404/g8.2023.03.007

Yang, S. (2016). The relationship between social support, self-efficacy, and satisfaction with physical activity among adolescents. *J. Wuhan Sports Univ.* 50, 90–94. doi: 10.15930/j.cnki.wtxb.2016.02.015

Yoon, H.-L., Ki-Ho, K., and Kyung-Ryur, K. (2020). The effect of professionalism of instructors perceived by Pilate participants on flow experience and leisure attitude. *Kor. Soc. Sports Sci.* 29, 263–275. doi: 10.35159/kjss.2020.04.29.2.263

Yu, H., An, S., Tao, Y., and Austin, L. (2022). Correlation and change in physical activity and physical fitness across four years of college students after one year of COVID-19 lockdown. *Healthcare* 10:1691. doi: 10.3390/healthcare10091691

Yu, P., and Hu, J. (2009). An exploratory study of fluency experiences in the content of college physical Education instruction. *Sci. Technol. Inform.* 23, 18–19+35.

Zhang, W. (2015). *Research on the development and reform of school sports policy in China*. [PhD's thesis] Wuhan (HB): Central China Normal University.

Zhang, H. (2019). An antecedent study of MOOC students' willingness to return - the moderating effect of course difficulty level. *Softw. Eng.* 22, 50–55. doi: 10.19644/j.cnki.issn2096-1472.2019.08.016

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Impact of motor self-efficacy on cyberbullying in adolescents and pre-adolescents in physical education

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Introduction: In recent years, cyberbullying rates have increased, especially among adolescents in the school environment. According to the literature, the factors that influence this type of behavior are access to technologies, physical activity and BMI, among others.

Aim: The aim is to find correlations between motor self-efficacy and cyberbullying.

Methods: The ECIP-Q and E-AEM questionnaire was applied to 1,232 students from Spanish schools and institutes (8–18 years old) in a cross-sectional study.

Results: Significant inverse correlations were found between the ECIP-Q and the E-AEM on the variables of gender, educational stage, daily physical activity, BMI, telephone ownership and hours spent on the Internet.

Conclusion: In conclusion, it can be understood that the higher the level of self-efficacy, the lower the level of abuse and victimization. Therefore, physical activity could be considered to act as a regulator of cyberbullying. And it would be interesting for public administrations to increase the number of hours of physical education, to expand out-of-school physical activities and to promote an active lifestyle in order to eradicate this type of abusive school behavior.

KEYWORDS
motor self-efficacy, ECIP-Q, E-AEM, cyberbullying, physical activity

1 Introduction

The lifestyle habits of citizens have changed over time, going from a more active lifestyle to a much more sedentary lifestyle. Currently, sedentary lifestyle rates in Spain are alarming; the population aged between 15 and 69 years does not meet the minimum physical activity recommendations proposed by the World Health Organization (WHO). Specifically, the latest data published by the Ministry of Health, Consumer Affairs, and Social Welfare reveal that 14% of children spend their free time on sedentary activities, which is more common in girls than in boys. In addition, 73.9% of children spent more than 1 h during the week with an electronic device, including tablets, smartphones, computers, and video games, increasing to 92.6% on weekends (Ministerio de Sanidad, 2018). Another more recent study conducted in the Spanish population revealed that 52.9% of children aged 6–10 years spend more than 2 h in front of screens for leisure and recreation purposes, rising to 67% in children aged 10–14 years, revealing an increase in screen time as they get older (Pons et al., 2021).

Unfortunately, this increased use of the Internet and social networks by children has led to the emergence of cyberbullying, a somewhat unpleasant phenomenon. This type of behavior is defined as a relatively new phenomenon that modifies traditional bullying, which is described as an unbalanced power relationship between perpetrator-victims, in which malicious actions are repeated, ranging from derogatory nicknames to degradation and manipulation of physical and material aggression (Menesini and Nocentini, 2009). Cyberbullying adapts to social networks, relying on anonymity frequently in chats or social networks, although there are other methods, such as the manipulation of photographs, which are often used in the context of cyberbullying (Roland, 2002; Hamburger et al., 2011; Gladden et al., 2014; Hinduja and Patching, 2019) . This type of bullying can occur in any context (Kowalski et al., 2018), although it is much more frequent in schools and institutes, since adolescence is the period in which personality is formed and many changes occur at a physical level, establishing a sensitive period, involving the one who executes it, the one who suffers it, and the witnesses that this activity is taking place. The consequences for victims of cyberbullying are very negative, seriously deteriorating their physical and mental health because they can develop depressive disorders, anxiety, personality, eating behavior, suicidal behaviors and thoughts, self-harm, and isolation, among other types of pathologies (Moore et al., 2017; Armitage, 2021). In the European Union, studies report a cyberbullying rate ranging from 5.5 to 44%, depending on the country. In recent years, the number of cases has significantly increased. In Spain, although the rate is among the lowest in Europe, 26.65% of adolescents claim to have been victims of cyberbullying (Athanasiou et al., 2018), accounting for more than a quarter of those surveyed, and this trend has been on the rise in the last few years (Zych et al., 2016). One of the most bullied profiles at school is a student with a body mass index (BMI) above the average, with overweight and obesity being one of the groups that performs the least physical activity and has the lowest physical self-perception (Storch et al., 2006). To quantify and characterize this phenomenon, a measurement tool was developed in the form of a scale called the European Cyberbullying Intervention Project Questionnaire (ECIP-Q) (Del Rey et al., 2015). This questionnaire is composed of 22 items differentiated into two dimensions, that of the victim and that of the abuser, and is designed to identify situations of harassment or victimization.

In this sense, the scientific literature has studied the behavior of students with the aim of identifying which factors are involved in the development of this dangerous type of behavior in order to intervene effectively and improve students' experience at school so that they can obtain the best possible learning outcomes. One of the factors studied is perceived self-efficacy, defined as the perception and feeling of capability regarding the tasks and challenges that appear in people's daily lives and their ability to face and overcome them satisfactorily, controlling these situations (Hernández-Álvarez et al., 2011). With the aim of developing a tool that allows the measurement of this construct and enables comparison with other variables, the (E-AEM), a scale composed of 10 items, was developed (Hernández-Álvarez et al., 2011). Self-efficacy has been studied as a determining factor in academic performance, finding positive correlations in fields such as mathematics and language (Hayat et al., 2020; Luo et al., 2023), in the field of physical activity, specifically in motor self-efficacy, it has been determined that the perception of self-efficacy acts as a mediator in the regulation of behavior, directly associated with the practice of physical activity in youth and, therefore, with the appearance of aggressive or undesired behaviors (Welk and Schaben, 2004; Greco, 2021). Authors who have studied the possible relationships between physical activity and behavior have found that physical activity is an ideal and effective means for the transmission of prosocial and positive values, while those who practice physical activity on a recurrent basis are less likely to develop problematic behaviors, including a lower probability of bullying and cyberbullying (Portolés Ariño and González Fernández, 2015; González et al., 2016; Arcila-Arango et al., 2022). In addition, negative correlations have been found between the practice of physical activity and bullying related to the physical appearance and weight of victims, where those with a higher BMI practice less physical activity (Storch et al., 2006; Losekam et al., 2010), establishing a high correlation between BMI and the likelihood of teasing by peers (Ievers-Landis et al., 2019).

The life stage in which this type of bullying occurs most often is childhood and adolescence. Studies have examined the factors that predict cyberbullying, finding a correlation with age, although only in adolescence, since older adolescents tend to perpetrate it more than younger adolescents and children, although in adulthood it is only higher in younger adults (Yudes et al., 2020). Since cyberbullying has become a highly prevalent social problem that greatly affects the mental health of adolescents, it is important to identify the factors involved in the development and profile of those who suffer it, with the intention of developing strategies to help reduce this incidence and the effects of this harmful practice. Therefore, this study aimed to explore the possible correlations between motor self-efficacy and cyberbullying, using the E-AEM scale and the ECIP-Q questionnaire, as a function of different variables: gender, educational stage, BMI, and the use and possession of electronic devices.

2 Materials and methods

2.1 Design

This work was designed as a cross-sectional study as defined in Setia (2016). It was carried out in schools and institutes in the autonomous community of Extremadura, Spain, during the year 2022.

2.2 Participants

According to the Census Report provided by the National Institute of Statistics,[1] there are 43,043 inhabitants between 8 and

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18 years of age in the autonomous community of Extremadura (Spain). The sample size was 1,232 participants exceeding 381 participants for a Confidence Level of 95%, with a margin of error of ±5%. A non-probability convenience sampling technique was used to select the appropriate sample size (Salkind, 1999). The final sample consisted of 1,232 students from schools and institutes of the community of Extremadura, belonging to primary education (from 8 to 11 years old), secondary education (from 12 to 16 years old), or high school (from 16 to 18 years old). Of the total number of students, 49.1% were boys and 50.9% were girls, establishing a fairly balanced sample with respect to gender. Most of the participants stated that they had a smartphone (Yes = 97.9%; No = 2.1%) and that they had access to different electronic devices with Internet connections (Yes = 90.7%; No = 1.5%; Sometimes = 7.7%). The characteristics of the sample are listed in **Table 1**.

2.3 Instruments

Sociodemographic Questionnaire: To collect sociodemographic data from the sample, they were provided with a specific questionnaire containing questions on the variables shown in **Table 1**: age, sex, possession of a smartphone, access to electronic devices with Internet connections, such as computers and tablets, cyberbullying, and physical activity.

TABLE 1 Sociodemographic profile of physical education students (N = 1232).

Variables	Categories	*N*	%
Gender	Boy	605	49.1
	Girl	627	50.9
Age	8–11 years	64	5.2
	12–15 years	752	61.0
	16–18 years	416	33.8
Do you have a smartphone?	Yes	1206	97.9
	No	26	2.1
Do you have a computer, tablet or other device with internet connection?	Yes	1118	90.7
	No	19	1.5
	Sometimes	95	7.7
Do you think there is cyberbullying in your school?	Yes	261	21.2
	No	270	21.9
	I don't know	701	56.9
Have you ever suffered a situation of cyberbullying by a classmate?	Yes	118	9.6
	No	1114	90.4
Do you think that people who suffer cyberbullying have a negative influence on their academic performance?	Yes	1097	89.1
	No	22	1.8
	I don't know	113	9.2

N: number, %: percentage.

The European Cyberbullying Intervention Project Questionnaire (ECIP-Q): This scale, validated by Del Rey et al. (2015), is composed of 22 items divided into two dimensions: (1) that of the bully, composed of 11 items aimed at measuring the frequency, duration, and severity of cyberbullying actions (example: 1- I have said swear words to someone or insulted them using SMS or Internet messages; and (2) the victim, composed of 11 items aimed at measuring the emotional and behavioral responses that appear as a consequence of cyberbullying (example: 1- Someone has said swear words to me or insulted me using email or SMS; and (2) Someone has hacked my account and impersonated me). For quantification, the questionnaire used a Likert-type scale ranging from 0 (never) to 4 (always). The authors (Del Rey et al., 2015) reported a reliability value of Cronbach's alpha coefficient: total = 0.87, victimization = 0.80, aggression = 0.88).

Motor Self-Efficacy Scale (E-AEM): This instrument was validated in Spanish for school-aged children by Hernández-Álvarez et al. (2011) consists of 10 items that present possible situations experienced during physical sports practice (e.g., Item 1: During a sports game, I can get into trouble even if someone opposes me; Item 7: Whatever happens during a sports game, I am usually able to handle the situation). Respondents indicated their level of agreement on a Likert-type scale, with values ranging from 1 ("strongly disagree") to 4 ("strongly agree"). Scores were calculated by summing up the 10 items, with possible scores ranging from 10 (indicating a low level of motor self-efficacy) to 40. The instrument has a reliability value of 0.82 based on Cronbach's alpha coefficient.

2.4 Procedure

In order to collect a sample for the study, the researchers accessed the database of the Department of Education and Employment of the Regional Government of Extremadura to identify schools where physical education (PE) is taught to students aged 8–18. They then contacted PE teachers at these schools by email, explaining the study's objectives and requesting that they arrange for a researcher to visit the school to administer a questionnaire on cyberbullying to students whose parents had provided informed consent. The questionnaire included sociodemographic questions as well as the ECIP-Q and E-AEM scales. Students were given a tablet to access the questionnaire via a Google Form, and each question was explained to them to avoid any confusion. Once all the questionnaires were collected, the researchers processed and anonymized the data before passing it on to another researcher for blind analysis.

In order to carry out this research, a protocol was adhered to following the considerations of the Declaration of Helsinki and this protocol was approved by the Biosafety and Bioethics Committee of the University of Extremadura in Spain (Registration Code 72/2022).

2.5 Statistical analysis

SPSS statistical software version 23 for MAC (IBM SPSS, Chicago, IL, USA) was used to process the collected data. First, the Kolmogorov-Smirnov test was used to explore the assumption of normality in the distribution of continuous variable data. It was found that this assumption was not met, so nonparametric statistical tests were used. Spearman's Rho test was used to analyze the relationship between each of the ECIPQ dimensions and the E-AEM scores. To interpret the correlation coefficients, the thresholds proposed by Mondragón Barrera (2014), were followed: rom 0.01 to 0.10 (low correlation), from 0.11 to 0.50 (medium correlation), from 0.51 to 0.75 (considerable correlation), from 0.76 to 0.90 (very high correlation) and from 0.91 to 1.00 (perfect correlation). Cronbach's alpha and McDonalds omega were used to analyze the reliability of each instrument. To interpret the values of the reliability test, we took as a reference those set out by Nunnally and Bernstein (1994): <0.70 (low), 0.71–0.90 (satisfactory) and >0.91 (excellent). To ensure the integrity and quality of the data, to give robustness to the accuracy of trends and patterns within our study sample, an outlier study was conducted that involved detailed inspection of extreme values for all items in individual responses. Those responses whose values in all items of the scale (32) were extreme were eliminated.

3 Results

Spearman's Rho test was used to analyze the relationship between the different dimensions of the ECIPQ and the E-AEM scores (**Table 2**). Significant inverse associations were found between the two dimensions of ECIPQ and E-AEM scores. However, the ECIPQ dimension concerning the victim showed a low correlation, whereas the second dimension concerning the abuser exhibited a moderate correlation. According to gender, all correlations were inverse, showing higher correlations in male students. In contrast, female students did not show significant associations between the first dimension of the ECIPQ and the E-AEM. Similarly, inverse correlations were found when evaluating the associations according to the educational stage to which the student belonged, manifesting higher correlations in the primary education stage; however, the only non-significant result was manifested when correlating the first dimension of the ECIPQ and E-AEM in the primary education stage.

Regarding the relationship between the ECIPQ and E-AEM (**Table 3**), the daily PA performed by the students generated disparate results. On the one hand, students who performed less than 60 min did not show significant correlations between the ECIPQ and E-AEM. However, those who performed more than 60 min daily showed inverse and medium correlations, although the only significant association was between the second dimension and E-AEM score. Similarly, underweight students showed significant mean and inverse correlations between both ECIPQ and E-AEM dimensions. Similarly, students with a healthy weight showed low inverse correlations, significant only in the second dimension of the ECIPQ. Finally, in overweight children, the trend was reversed with positive correlations; however, none of these correlations were significant.

Table 4 shows the correlations between both scales when considering the daily hours spent in front of technological devices and students' possession of a cell phone. Students who spent less than an hour and a half in front of a device showed significant and average inverse correlations. By contrast, those who exceeded the general recommendations showed a low and significant inverse association. Likewise, students who do not have a cell phone show inverse, medium and significant associations, while those who do have a mobile phone also show inverse and significant, but low associations.

Finally, the reliability values of Cronbach's alpha and McDonalds' omega for each of the dimensions studied are presented in **Table 5**. Thus, the values of the ECIPQ were considered satisfactory and those of the E-AEM, excellent.

4 Discussion

The aim of this study was to search for and identify correlations between the ECIP-Q questionnaire and the E-AEM scale, as well as to compare these scores between gender, educational stage, BMI, hours of daily physical activity, time dedicated to technologies, and possession of these technological devices.

First, an inverse and significant correlation was found between the E-AEM scale scores and both dimensions of the ECIP-Q questionnaire of average character in the abuser, which means that the higher the score on the motor self-efficacy scale, the lower the score on this dimension, establishing that the abuser is less likely to commit actions of this style if he/she has higher motor self-efficacy. In this sense, authors who have explored the behaviors of students in relation to motor self-efficacy have found results in line with what has been described, establishing that a better motor self-efficacy could be related to a better regulation of behavior and an increase in empathy towards peers, decreasing this type of disruptive behavior (Greco, 2021; Arcila-Arango et al., 2022). Other studies have found that a higher level of self-efficacy can reduce the likelihood of students being victimized by cyberbullying. This can be considered a useful tool for preventing disruptive behavior (Kokkinos et al., 2015). According to these results, designing strategies that increase students' motor self-efficacy would reduce cyberbullying rates because there would be fewer abusive behaviors and fewer victims of this phenomenon, thus improving students' coexistence. Regarding the gender variable, significant inverse correlations were found in both genders and dimensions, except in the first dimension of the ECIP-Q in females. These associations were higher in males, with an average character in both dimensions. These results coincide with those obtained in other studies conducted in the exploration of motor self-efficacy, where boys had higher self-efficacy than girls (Hernández-Álvarez et al., 2011; Chen et al., 2019; Ortiz Gómez, 2021). In the same way, the correlation is higher in boys than in girls in both dimensions; this behavior can be explained by what is found in the scientific literature, which suggests that boys are more likely to occupy the role of abusers than girls (Smith et al., 2019), although there are discrepancies about which gender tends to occupy the role of the victim more (Chocarro de Luis and Garaigordobil Landazabal, 2019; Smith et al., 2019). Regarding educational stage, the results show a significant inverse association in both dimensions in the secondary stage and in the second dimension in the primary stage. Students in primary education obtain a higher correlation in general, with motor self-efficacy gaining more importance; these results express that self-efficacy decreases with age, and the significant medium inverse correlation of the abuser dimension of

TABLE 2 Correlation between ECIPQ dimensions and E-AEM scores according to student gender and educational stage.

Dimensions	E-AEM ρ (p)	Gender		Educational stage	
		Men	Women	Primary	Secondary
(1) ECIPQ-Victim	−0.08 (<0.01)**	−0.12 (<0.01)**	−0.03 (0.53)	−0.19 (0.11)	−0.07 (0.02)*
(2) ECIPQ-Abuser	−0.11 (<0.01)**	−0.13 (<0.01)**	−0.09 (0.03)*	−0.27 (0.02)*	−0.10 (<0.01)**

The correlation is significant at the $^{**}p < 0.01$; $^{*}p < 0.05$. Each score obtained is based on a Likert scale: E-AEM (1–4): 1 (strongly disagree) to 4 (strongly agree). ECIP-Q (0–4): 0 (never) to 4 (always).

TABLE 3 Correlation between the ECIPQ dimensions and the E-AEM score as a function of hours of daily PA and BMI.

Dimensions	E-AEM ρ (p)	Hours of daily physical activity		BMI		
		<60 min	>60 min	<18.5	18.5–24.9	≥25
ECIPQ-Victim	−0.08 (<0.01)**	0.03 (0.75)	−0.34 (0.37)	−0.18 (<0.01)**	−0.07 (0.06)	0.16 (0.07)
ECIPQ-Abuser	0.11 (<0.01)**	−0.14 (0.14)	−0.11 (<0.01)**	−0.17 (<0.01)**	−0.10 (<0.01)**	0.01 (0.93)

The correlation is significant at the $^{**}p < 0.01$. Each score obtained is based on a Likert scale: E-AEM (1–4): 1 (strongly disagree) to 4 (strongly agree). ECIP-Q (0–4): 0 (never) to 4 (always).

TABLE 4 Correlation between ECIPQ dimensions and E-AEM scores as a function of daily hours in front of a technological device and owning a telephone.

Dimensions	E-AEM ρ (p)	Hours per day in front of computer/tablet/mobile phone		Own telephone?	
		<90 min	>90 min	No	Yes
ECIPQ-Victim	−0.08 (<0.01)**	−0.22 (0.20)*	−0.06 (0.04)*	−0.47 (0.02)*	−0.07 (0.02)*
ECIPQ-Abuser	−0.11 (<0.01)**	−0.32 (<0.01)**	−0.09 (<0.01)**	−0.43 (0.03)*	−0.10 (<0.01)**

The correlation is significant at the $^{**}p < 0.01$; $^{*}p < 0.05$. Each score obtained is based on a Likert scale: E-AEM (1–4): 1 (strongly disagree) to 4 (strongly agree). ECIP-Q (0–4): 0 (never) to 4 (always).

TABLE 5 Reliability values of Cronbach's alpha and McDonalds' omega.

Dimensions	Cronbach's alpha	McDonalds' omega
ECIPQ-Victim	0.874	0.865
ECIPQ-Abuser	0.877	0.861
E-AEM	0.907	0.909

the ECIP-Q explains that, the higher the self-efficacy, the lower the incidence of this role in this educational stage. The authors agree that the decrease in self-efficacy with age may be due to the self-esteem problems reported in adolescence (Hernández et al., 2008; Velázquez Buendía et al., 2015; Perea Chafé et al., 2016). This is a sensitive period in which personality and social circles are formed, making this population prone to a decline in self-esteem and the appearance of these risky behaviors. However, motor self-efficacy can act as a regulator of this behavior.

Continuing the results of the exploration between the dimensions of the ECIP-Q and E-AEM scores as a function of physical activity and BMI, significant correlations were found only in students who performed >60 min of physical activity per day, with an inverse and average character. Therefore, those who performed more than 60 min of physical activity per day had greater motor self-efficacy and scored lower on the ECIP-Q abuser dimension. The results obtained by the scientific community support those obtained in this work, stating that physical activity, in addition to being an emotional regulator and ideal means for the promotion of values, is an effective tool for implementing programs that decrease the incidence of cyberbullying (García-Hermoso et al., 2020; Benítez-Sillero et al., 2021; Benitez-Sillero et al., 2022). Additionally, other studies have determined that students who are more physically active have less time to use phones or other technologies, so these rates of cyberbullying would also decrease Relative to BMI, the results show significant correlations of inverse nature and mean magnitude in both dimensions of the ECIP-Q in students with a BMI below 18.5 and those with a BMI between 18.5 and 24.9 in the bully dimension. This correlation implies that students who are in the underweight range and have higher scores on motor self-efficacy are less likely to be in the role of bullies or victims of cyberbullying, and those in the normo weight on the bully dimension. Studies on the relationships between BMI, motor self-efficacy, and cyberbullying are scarce, and studies carried out to date have examined the influence of overweight and obesity in both roles, determining that both increase the probability of being a victim of cyberbullying (Lee et al., 2018; Carvalho et al., 2021), although the results of this study did not show significant associations in people with a BMI over 25.

Finally, regarding the correlations between the dimensions of the ECIP-Q and E-AEM according to the time spent on technologies and the possession of a smartphone, significant correlations were obtained in all dimensions and variables. The strongest associations occur in those who spend less than 90 days with electronic devices and do not have their own phones, both in the abuser and victim dimensions. Research published in this area shows similar results, identifying as risk factors the time spent on screens and the possession of one's own phone and Internet, establishing that the more time, the greater the probability of suffering and executing it (Chen et al., 2017; You and Lim, 2018; Redondo Pacheco, 2023).

Lastly, the results showed that the higher the motor self-efficacy, the lower the perpetration of cyberbullying, both in the dimension of abusers and victims in different populations. Knowing how the variables behave helps to understand the profiles and behaviors of this phenomenon, establishing the lines of action that should be taken in the future to curb these situations. In this sense, studies on motor self-efficacy report that it is higher in those who are physically active, as in the results obtained in this paper, establishing this variable as a useful tool to reduce cyberbullying situations through prosocial values and the use of more time exercising, being farther away from social networks and the Internet (García Puello et al., 2020; Sheikh et al., 2022).

4.1 Practical applications

The results of this study reveal information about the research gap, knowing the correlations and behaviors of the variables that influence the appearance of these behaviors, contributing to the knowledge of the factors involved in cyberbullying, both in the role of abusers and victims, with the aim of promoting practices that prevent the occurrence of these behaviors. The results obtained in this study show that those who engage in more physical activity have more motor self-efficacy and are therefore less likely to perpetrate the behaviors that characterize cyberbullying as well as being less likely to suffer it. Physical activity is also related to healthier lifestyles, with a lower incidence of overweight and obesity, which is one of the most influential factors in bullying. Thus, it seems logical to propose that the promotion of physical activity is an effective means of reducing cyberbullying rates. This promotion could be done from educational institutions through physical education or from other institutions, such as municipalities, with physical activity workshops that promote positive values and awareness of this type of behavior.

4.2 Limitations and future lines

The results obtained in this study should be interpreted with caution, as they present some limitations. Since this is a cross-sectional study, causal relationships cannot be established, and electronic questionnaires were used, which have both advantages and disadvantages. Moreover, a non-random sampling method based on convenience sampling was used; therefore, the results should be interpreted with caution. Finally, caution must be taken in the interpretation of the results, since the sample belongs only to the community of Extremadura, and there may be cultural factors that influence the results obtained. In the future, it would be interesting to replicate the study in other communities to increase the sample to other contexts; also, it would be interesting to repeat this study in other samples to obtain data on the variables of motor self-efficacy and cyberbullying, since the scientific literature on this topic is quite scarce, and it is difficult to compare the results.

5 Conclusion

The ECIP-Q and E-AEM scales were used to measure motor self-efficacy and cyberbullying bully-victim behavior. The results showed an inverse correlation (for all variables), whereby the higher the motor self-efficacy, the lower the incidence of both dimensions of cyberbullying, measured in different populations. In general, boys scored higher on the E-AEM scale and had a higher correlation with cyberbullying, as did primary school boys than secondary school boys. Moreover, those who performed more than 60 min of daily physical activity had a higher score in motor self-efficacy, although only in the bullying dimension. With respect to BMI, they are the ones who have underweight a higher correlation in both dimensions, without finding significant correlations in those with a BMI greater than 25. Finally, the strongest associations of an inverse nature are higher in those who do not have their own telephone and spend less time on technologies. Based on these results, it is worth considering that it is necessary to implement strategies to ensure that they comply with the maximum recommended time in front of screens, one of which is physical activity, as it increases motor self-efficacy and keeps them away from screens for the duration of the activity. On the other hand, it is a means to promote positive values that could increase empathy and decrease the incidence of cyberbullying.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Bioethic Comitée of University of Extremadura (Spain). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. The use of the data in this study did not require the approval of an accredited ethics committee as it is not covered by data protection principles, i.e., it is non-identifiable and anonymized data collected through an anonymous survey for elite athletes. Furthermore, under Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of individuals with regard to the processing of personal data and on the free movement of such data (which entered into force on 25 May 2016 and is binding as of 25 May 2018), data protection principles need not be applied to anonymous information (i.e., information relating to an identifiable natural person, nor to data of a subject who is not, or is no longer, identifiable). Therefore, the Regulation does not affect the processing of our information.

Even for statistical or research purposes, its use does not require the approval of an accredited Ethics Committee.

Author contributions

JR-R: Data curation, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review and editing. AC-P: Funding acquisition, Investigation, Methodology, Resources, Visualization, Writing – original draft, Writing – review and editing. NM-P: Conceptualization, Formal Analysis, Investigation, Writing – original draft, Writing – review and editing. CG-A: Investigation, Project administration, Supervision, Visualization, Writing – original draft, Writing – review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Arcila-Arango, J.-C., Correderas-Campuzano, Farias Valenzuela, C., Giakoni Ramírez, F., and Valdivia-Moral, P. (2022). Self-concept and bullying in secondary school physical education: a sysmatic review. *J. Sport Health Res.* 14, 1–12.

Armitage, R. (2021). Bullying in children: impact on child health. *bmjpo* 5:e000939. doi: 10.1136/bmjpo-2020-000939

Athanasiou, K., Melegkovits, E., Andrie, E. K., Magoulas, C., Tzavara, C. K., Richardson, C., et al. (2018). Cross-national aspects of cyberbullying victimization among 14–17-year-old adolescents across seven European countries. *BMC Public Health* 18:800. doi: 10.1186/s12889-018-5682-4

Benítez-Sillero, J. D., Armada Crespo, J. M., Ruiz Córdoba, E., and Raya-González, J. (2021). Relationship between amount, type, enjoyment of physical activity and physical education performance with Cyberbullying in adolescents. *Int. J. Environ. Res. Public Health* 18:2038. doi: 10.3390/ijerph18042038

Benitez-Sillero, J. D., Ortega-Ruiz, R., and Romera, E. M. (2022). Victimization in bullying and Cyberbullying and organized physical activity: the mediating effect of physical self-concept in adolescents. *Eur. J. Dev. Psychol.* 19, 810–827. doi: 10.1080/17405629.2021.1967136

Carvalho, M., Branquinho, C., and de Matos, M. G. (2021). Cyberbullying and bullying: impact on psychological symptoms and well-being. *Child Ind. Res.* 14, 435–452. doi: 10.1007/s12187-020-09756-2

Chen, H., Dai, J., and Gao, Y. (2019). Measurement invariance and latent mean differences of the chinese version physical activity self-efficacy scale across gender and education levels. *J. Sport Health Sci.* 8, 46–54. doi: 10.1016/j.jshs.2017.01.004

Chen, L., Ho, S. S., and Lwin, M. O. (2017). A meta-analysis of factors predicting Cyberbullying perpetration and victimization: from the social cognitive and media effects approach. *New Media Soc.* 19, 1194–1213. doi: 10.1177/1461444816634037

Chocarro de Luis, E., and Garaigordobil Landazabal, M. (2019). Bullying y cyberbullying: diferencias de sexo en víctimas, agresores y observadores. *Pensamiento Psicológico* 17, 57–71. doi: 10.11144/doi:10.11144/Javerianacali.PPSI17-2.bcds

Del Rey, R., Casas, J. A., Ortega-Ruiz, R., Schultze-Krumbholz, A., Scheithauer, H., Smith, P., et al. (2015). Structural validation and cross-cultural robustness of the European cyberbullying intervention project questionnaire. *Comput. Hum. Behav.* 50, 141–147. doi: 10.1016/j.chb.2015.03.065

García Puello, F., Herazo Beltrán, Y., Sánchez Guette, L., Barbosa Villa, E. J., Coronado Rodríguez, A. D. C., and Corro Rueda, E. A. (2020). *Autoeficacia Hacia la Actividad Física en Escolares Colombianos*. Retos: Nuevas Tendencias en Educación Física, Deportes y Recreación.

García-Hermoso, A., Hormazabal-Aguayo, I., Oriol-Granado, X., Fernández-Vergara, O., and del Pozo Cruz, B. (2020). Bullying victimization, physical inactivity and sedentary behavior among children and adolescents: a meta-analysis. *Int. J. Behav. Nutr. Phys. Act* 17:114. doi: 10.1186/s12966-020-01016-4

Gladden, R. M., Vivolo-Kantor, A. M., Hamburger, M. E., and Lumpkin, C. D. (2014). *Bullying Surveillance Among Youths: Uniform Definitions for Public Health and Recommended Data Elements; National Center for Injury Prevention and Control*. Washington, DC: U. S. Department of Education.

González, J. I. Á, Ortega, F. Z., Garófano, V. V., Martínez, A. M., Sánchez, S. G., and Díaz, M. E. (2016). Actividad física de adolescentes: implicación de sustancias nocivas, modalidad practicada y familia. *Psicol. Esc. Educ.* 20, 13–22. doi: 10.1590/2175-353920150201908

Greco, G. (2021). Multilateral teaching in physical education improves resilience and self-efficacy in adolescents and could help reduce bullying behaviors. *Phys. Cult. Sport Stud. Res.* 90, 1–9. doi: 10.2478/pcssr-2021-0008

Hamburger, M. E., Basile, K. C., and Vivolo, A. M. (2011). *Measuring Bullying Victimization, Perpetration, and Bystander Experiences: a Compendium of Assessment Tools*. Atlanta, GA: Centers for Disease Control and Prevention. doi: 10.1037/e580662011-001

Hayat, A. A., Shateri, K., Amini, M., and Shokrpour, N. (2020). Relationships between academic self-efficacy, learning-related emotions, and metacognitive learning strategies with academic performance in medical students: a structural equation model. *BMC Med. Educ.* 20:76. doi: 10.1186/s12909-020-01995-9

Hernández, J.-L., Velázquez, R., Martínez, M. E., Garoz, I., López, C., and López, Á (2008). Frequency of physical activity in children and teenagers: relation with their perception of motor self-efficacy, practice within their social environment, and their satisfaction with physical education. *J. Study Educ. Dev.* 31, 79–92. doi: 10.1174/021037008783487129

Hernández-Álvarez, J. L., Velázquez-Buendía, R., Eugenia, M., and Garoz-Puerta, I. (2011). Self-efficacy motor scale: psychometric properties and the results of its application to the spanish School population. *Revista de Psicologia del Deporte* 20, 13–28.

Hinduja, S., and Patching, J. W. (2019). *Cyberbullying Identification, Prevention, and Response; Cyberbullying Research Center*. Available Online at: https://cyberbullying.org/Cyberbullying-Identification-Prevention-Response-2023.pdf (accessed June 30, 2023).

Ievers-Landis, C. E., Dykstra, C., Uli, N., and O'Riordan, M. A. (2019). Weight-related teasing of adolescents who are primarily obese: roles of sociocultural attitudes towards appearance and physical activity self-efficacy. *Int. J. Environ. Res. Public Health* 16:1540. doi: 10.3390/ijerph16091540

Kokkinos, C. M., Panagopoulou, P., Tsolakidou, I., and Tzeliou, E. (2015). Coping with bullying and victimisation among preadolescents: the moderating effects of self-efficacy. *Emot. Behav. Difficulties* 20, 205–222. doi: 10.1080/13632752.2014.955677

Kowalski, R. M., Toth, A., and Morgan, M. (2018). Bullying and cyberbullying in adulthood and the workplace. *J. Soc. Psychol.* 158, 64–81. doi: 10.1080/00224545.2017.1302402

Lee, B., Jeong, S., and Roh, M. (2018). Association between body mass index and health outcomes among adolescents: the mediating role of traditional and cyber bullying victimization. *BMC Public Health* 18:674. doi: 10.1186/s12889-018-5390-0

Losekam, S., Goetzky, B., Kraeling, S., Rief, W., and Hilbert, A. (2010). Physical activity in normal-weight and overweight youth: associations with weight teasing and self-efficacy. *OFA* 3, 239–244. doi: 10.1159/000319433

Luo, Q., Chen, L., Yu, D., and Zhang, K. (2023). The mediating role of learning engagement between self-efficacy and academic achievement among chinese college students. *PRBM* 16, 1533–1543. doi: 10.2147/PRBM.S401145

Menesini, E., and Nocentini, A. (2009). Cyberbullying definition and measurement: some critical considerations. *Zeitschrift Psychol.* 217, 230–232. doi: 10.1027/0044-3409.217.4.230

Ministerio de Sanidad (2018). *Consumo y Bienestar Social ENSE Encuesta Nacional de Salud España 2017 (Spanish Health National Survey 2017).* Madrid: Gobierno de España.

Mondragón Barrera, M. A. (2014). Uso de La correlación de spearman en un estudio de intervención en fisioterapia. *Mov. Cient.* 8, 98–104.

Moore, S. E., Norman, R. E., Suetani, S., Thomas, H. J., Sly, P. D., and Scott, J. G. (2017). Consequences of bullying victimization in childhood and adolescence: a systematic review and meta-analysis. *World J. Psychiatry* 7, 60–76. doi: 10.5498/wjp.v7.i1.60

Nunnally, J. C., and Bernstein, I. H. (1994). *Psychometric Theory; McGraw-Hill Series in Psychology*, 3rd Edn. New York: McGraw-Hill.

Ortiz Gómez, A. (2021). *Self-Concept, Motor Competence and Motor Self-Efficacy: Relationships and Influence on the Practice of Physical Activity Among primary School Students in the Community of Madrid*. Ph.D. Thesis. Madrid: Universidad Autónoma de Madrid.

Perea Chafé, J., Parra-Camacho, D., and Pérez Campos, C. (2016). Analysis of the secondary education student's perception of their degree of motor self-efficacy in relation to the subject of physical education. *Calidad de vida y salud* 9, 104–119.

Pons, M., Bordoy, A., Alemany, E., Huget, O., Zagaglia, A., and Slyvka, S. (2021). Family habits related to theexcessive use of recreational screens (television and video games) in childhood. *Rev. Esp. Salud. Pública.* 95, 1–13.

Portolés Ariño, A., and González Fernández, J. (2015). Rendimiento académico y correspondencias con indicadores de salud física y psicológica. *Sportis Sci. J.* 1, 164–181. doi: 10.17979/sportis.2015.1.2.1409

Redondo Pacheco, J. (2023). Variables asociadas al fenómeno del ciberbullying en adolescentes colombianos. *PSICO* 41, 219–239. doi: 10.18800/psico.202301.009

Roland, E. (2002). Bullying, depressive symptoms and suicidal thoughts. *Educ. Res.* 44, 55–67. doi: 10.1080/00131880110107351

Salkind, N. J. (1999). *Métodos de Investigación*. México: Pearson educación.

Setia, M. S. (2016). Methodology series module 3: cross-sectional studies. *Indian J. Dermatol.* 61, 261–264. doi: 10.4103/0019-5154.182410

Sheikh, M., Bay, N., Ghorbani, S., and Esfahaninia, A. (2022). Effects of social support and physical self-efficacy on physical activity of adolescents. *Int. J. Pediatr. Masshad* 10, 15823–15834.

Smith, P. K., López-Castro, L., Robinson, S., and Görzig, A. (2019). Consistency of gender differences in bullying in cross-cultural surveys. *Aggress. Violent Behav.* 45, 33–40. doi: 10.1016/j.avb.2018.04.006

Storch, E. A., Milsom, V. A., DeBraganza, N., Lewin, A. B., Geffken, G. R., and Silverstein, J. H. (2006). Peer victimization, psychosocial adjustment, and physical activity in overweight and at-risk-for-overweight youth. *J. Pediatric Psychol.* 32, 80–89. doi: 10.1093/jpepsy/jsj113

Velázquez Buendía, R., Hernández Álvarez, J. L., Garoz Puerta, I., and Martínez Gorroño, M. E. (2015). Auto-eficacia motriz, educación física y actividad física en adolescentes brasileños y españoles / motor self-efficacy, physical education and physical activity in Brazilian and Spanish adolescents. *rimcafd* 60, 631–646. doi: 10.15366/rimcafd2015.60.002

Welk, G. J., and Schaben, J. A. (2004). Psychosocial correlates of physical activity in children-a study of relationships when children have similar opportunities to be active. *Meas. Phys. Educ. Exercise Sci.* 8, 63–81. doi: 10.1207/s15327841mpee0802_2

You, S., and Lim, S. A. (2018). Longitudinal predictors of cyberbullying perpetration: evidence from korean middle school students. *Pers. Individ. Dif.* 89, 172–176. doi: 10.1016/j.paid.2015.10.019

Yudes, C., Rey, L., and Extremera, N. (2020). Predictive factors of cyberbullying perpetration amongst Spanish adolescents. *Int. J. Environ. Res. Public Health* 17:3967. doi: 10.3390/ijerph17113967

Zych, I., Ortega-Ruiz, R., and Marín-López, I. (2016). Cyberbullying: a systematic review of research, its prevalence and assessment issues in Spanish studies. *Psicol. Educ.* 22, 5–18. doi: 10.1016/j.pse.2016.03.002

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Acquisition of educational values at the Real Madrid Foundation's social-sports schools

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The objective of this study was to analyse the impact of the educational programme of the Real Madrid Foundation (RMF) on the acquisition of educational values at social-sports football and basketball schools among children aged between 12 and 16 years in Italy, Romania, Spain and the United Kingdom. The most significant results showed that: (a) between the 20–21 and 21–22 seasons, there were statistically significant increases in personal and team success, self-fulfilment, personal and group superiority, health and physical fitness, and peaceful behaviour; and (b) the increase in variables being studied was different according to the country analysed in such a way that: in the per-sonal and team success dimension there was a rise in the United Kingdom and Italy; in self-fulfilment there was an increase in the United Kingdom; in the personal and group superiority dimension there was a rise in Italy and Romania; in the health and physical fitness dimension there was an increase in social-sports schools in the United Kingdom and Italy; in the peaceful behaviour dimension there was a rise in social-sports schools in the United Kingdom and a drop in social-sports schools in Romania. There were very significant improvements in the majority of dimensions and countries, although the development of the various dimensions is different and specific to every one of the distinct countries, meaning that it is necessary to keep adapting the educational programme of the Real Madrid Foundation in line with the sociocultural characteristics of each of the countries in which it is implemented.

KEYWORDS

personal and team success, self-fulfilment, personal and group superiority, health, peaceful behaviour

1 Introduction

Within teaching/learning of team sports, the new teaching/learning models based on cognitive constructivism processes and dynamic ecology, with their various approaches and distinctive features (Teaching Games for Understanding, Sport Education, Non-linear Paedagogy, Real Madrid Foundation Model, etc.) emphasise the need to create sport environments that follow certain principles of a paedagogical, physical-physiological, psychological, emotional, cognitive and social nature, in a controlled environment in order to maximise comprehensive development in children and youths (McCarthy et al., 2016; Torstveit et al., 2018; Vallence et al., 2019; Niemistö et al., 2020). A common and essential factor in all these new teaching/learning models is the need to promote values education among athletes, even designing teaching-learning models in which this aspect is the central axis, for example the "Social Responsibility Model" proposed by Hellison (2010), the "Sports Education Model" developed by Siedentop (1994), and the Real Madrid Foundation Project "For a REAL Education: Values and Sport" (Ortega-Vila et al., 2012; Ortega et al., 2021).

The Social-sports School model of the Real Madrid Foundation (RMF) “Por una Educación REAL: Valores y Deporte” (For a REAL Education: Values and Sport), is characterised by the following paedagogical approaches (Ortega et al., 2015): (a) educational values are the central axis on which the model is based; (b) inclusion and non-selection or discrimination (as regards level, gender or disability) are sought; (c) the coaches are mostly teachers; (d) the rules of the sport competition are adapted to the psycho-evolutionary characteristics of the athletes; and (e) there is an educational programme and family involvement. To implement the RMF model, regular educational activities are carried out for teachers, families and students participating in these sports schools. Likewise, the development processes of the model are decisive, through an educational evaluation that allows and favours the use of feedback and feedforward in educational matters.

The model is currently being implemented in more than 94 countries on five continents. In this respect, scientific literature stresses that it is increasingly necessary to carry out transcultural studies that make it possible to know to what extent the cultural factor of each country, territory, etc. may have an effect on generally doing sport itself (Rodríguez-Muñoz et al., 2021), on the perception that athletes have of sport values (Balish and Caron, 2015), the perception that mothers/fathers have of the important of values in sport (Bhalla and Weiss, 2010), on the relationship between values and emotions (Jin et al., 2017), the leadership style of coaches (Babbitt, 2019), on the need for coaches to adapt to the cultural environment of each country in order to achieve an appropriate education process (Borges et al., 2022), as well as on the typical effectiveness and adaptation of the different teaching models in particular (Sánchez-Gómez et al., 2014).

The objective of this study was to analyse the impact of the educational programme of the Real Madrid Foundation (RMF) on the acquisition of educational values (Personal and team success; Self-fulfilment; Personal and group superiority; Health and physical fitness; Peaceful behaviour) at social-sports football and basketball schools among children aged between 12 and 16 years in Italy, Romania, Spain and the United Kingdom.

2 Materials and methods

2.1 Participants

The sample was made up of 395 athletes from 4 countries (117 from Spain, 34 from Romania, 101 from Italy and 143 from the United Kingdom), aged between 12 and 16 years. This accounted for 60 girls and 335 boys belonging to a total of 21 RMF social-sports football and basketball schools. They had spent 1.7 ± 1.4 years on average doing sport at the RMF social-sports schools. A total of 191 athletes participated in the 2020–2021 season and 204 in the 2021–2022 season. Of the total number of athletes, 243 were novices at the RMF sports schools, meaning it was their first year, while 139 were veterans, meaning they had already participated in at least one season previously at the RMF sports schools.

2.2 Procedure and materials

The educational programme of the RMF was implemented which is called “Por una Educación REAL: Valores y Deporte”. This is a sport programme that places an emphasis on advancement and values education (respect, self-esteem, motivation, equality, autonomy, health and team spirit) by means of a comprehensive teaching methodology and changes to competition rules (Ortega et al., 2021). The programme was implemented for two seasons, in such a way that for 9 months each season, the athletes completed two training sessions a week, each lasting 1 h.

In order to record educational values, the Questionnaire on Values in Team Sports (CUVADE) (12–16 years) was used (Ruiz et al., 2017). The questionnaire was validated in Spanish, translated and adapted to English, Italian and Romanian. This tool comprised 29 items divided into six dimensions. Each item was answered by means of a five-point Likert scale, where 1 = not important at all and 5 = very important. The dimensions recorded in this tool are:

(a) Personal and team success (values related to the importance of winning, feeling of superiority, mastery of the sport. Example: Acting with firmness, determination and in an energetic way, in order to obtain an advantage over an opponent in a game situation);
(b) Self-fulfilment and pro-social conduct (importance given to enjoyment, self-acceptance, helping and supporting other peers. Example: Being accepted by others in the group);
(c) Sportsmanship and fair play (aspects related to respect, fairness, sportsmanship and tolerance. Example: Being sporty, polite to others and knowing how to act when winning and losing);
(d) Personal and group superiority (importance that young people give to the public image, to the feeling of superiority. Example: Feeling that we are superior to the rival team in the competition);

(e) Health and physical fitness (importance given to sport as an enabler of health and improved performance in sport. Example: Improving my fitness to improve my health);
(f) Peaceful behaviour (use of dialog as a means to resolve conflicts. Example: Acting peacefully, resolving conflicts, when they arise, through dialog).

The study was conducted in accordance with the Declaration of Helsinki, and approved by Ethics Committee (Comité Investigación Biomédica de Andalucía, PEIBA) (protocol code 0803-N-20; approved 23 July 2020).

2.3 Data analyses

A basic descriptive analysis of the main trends and deviations was carried out for each dimension and item, both overall and broken down into countries. The non-parametric Mann–Whitney *U*-test was used to analyse the general differences in the various dimensions between one sport season and another, making use of the rank-biserial correlation effect size.

In order to analyse the possible effect of the country in the development of educational values from one season to another, a two-way analysis of variance (2 × 4) was carried out on seasons (2020–2021 vs. 2021–2022) and country of the sports school (Italy, Romania, Spain and the United Kingdom), using the Bonferroni's *post-hoc* test. Eta squared was employed to measure the effect size using the following values of reference (Ferguson, 2009): no effect ($\eta^2 < 0.04$), small effect ($0.04 \leq \eta^2 < 0.25$), medium effect ($0.25 \leq \eta^2 < 0.64$), and large effect ($\eta^2 \geq 0.64$). All data were calculated using version 25.0 of the SPSS statistics programme, with a significance level of $p < 0.05$.

3 Results

Table 1 shows the means and standard deviations obtained in each of the dimensions for the 2020–2021 and 2021–2022 seasons. As regards the value ratings of the different dimensions, it was observed that the most highly valued in the 2020–2021 season were: Sportsmanship and fair play, and Health and physical fitness, while the least valued were: Personal and group superiority, Personal and team success; while in the 2021–2022 year the most highly valued was Health, physical fitness and team spirit and the least valued was Personal and group superiority.

When analysing the differences between the 2020–2021 and 2021–2022 years in Table 1, statistically significant increases were observed in all dimensions, except in Sportsmanship and fair play, where no statistically significant differences were found between the values of the 20–21 and 21–22 seasons.

Table 2 shows the arithmetic means obtained in each of the athlete dimensions in the 2020–2021 year, and in the 2021–2022 year, taking into account the country of the sports school of the participants.

After carrying out a two-way analysis of variance (2 × 4) on seasons (2020–2021 vs. 2021–2022) and country of the sports school (Italy, Romania, Spain, and the United Kingdom), it was observed that the interaction effect of the Season factor with the Country was not statistically significant in the Sportsmanship dimension [$F_{(3.384)} = 0.478$, $p = 0.689$, $\eta^2 = 0.004$]. It may therefore be stated that the interaction between both factors did not affect the changes brought about in these dimensions (see Figure 1).

On the contrary, statistically significant effects were observed in the dimensions of Personal and team success [$F(_{3.381)} = 23.172$, $p = 0.000$, $\eta^2 = 0.154$]; Self-fulfilment [$F_{(3.382)} = 3.644$, $p = 0.013$, $\eta^2 = 0.028$]; Personal and group superiority [$F_{(3.375)} = 8.304$, $p = 0.000$, $\eta^2 = 0.062$]; Health and physical fitness [$F_{(3.384)} = 6.456$, $p = 0.000$, $\eta^2 = 0.048$]; and Peaceful behaviour [$F_{(3.384)} = 2.938$, $p = 0.033$, $\eta^2 = 0.022$].

In Figure 1 it is seen that in the Personal and team success dimension, there is a statistically significant increase in the United Kingdom and Italy, and a slight decrease in Spain and Romania which is not statistically significant.

When analysing the Self-fulfilment dimension in Figure 2, a statistically significant in-crease is observed in the United Kingdom; as well as a slight increase in Italy, and a slight decrease in Romania and Italy, although in these cases there were no statistically significant differences.

On the other hand, when analysing the Personal and group superiority dimension, in Figure 3 a statistically significant increase is seen in Italy and Romania; as well as a slight increase in Spain and a slight decrease in Romania, although in these cases no statistically significant differences were recorded.

When analysing the Health and physical fitness dimension (see Figure 4), a statistically significant increase is seen in social-sports schools in the United Kingdom and Italy, and a slight decrease is observed in Romania and Spain, although in this case no statistically significant differences were recorded.

Lastly, when analysing the Peaceful behaviour dimension (Figure 5), a statistically significant increase is observed in social-sports schools in the United Kingdom and a statistically significant decrease is seen in social-sports schools in Romania. On the other hand, there is a slight increase in Italy and Spain.

4 Discussion

The objective of this study was to analyse the effects of the RMF model on athlete values, considering factors of multiculturalism, according to the country where the model is implemented. However, considerable improvements are observed in the majority of dimensions and countries, while the development of the various dimensions is different and specific to the distinct countries. This aspect implies the need to keep adapting the educational programme in line with the Sociocultural characteristics.

From a general perspective, sport is an ideal environment in which to develop skills of a social and attitudinal nature (Gutierrez et al., 2017). Some current methodological approaches take these values that are normally attributed to sport for granted without observing the necessary paedagogical intention that must go with it in order for the educational experience of sport to really be valuable and positive (Shields et al., 2018; Rivera-Mancebo et al., 2020).

To date, most scientific evidence has exclusively focussed on proposals and models related to physical education in the area of curricular and formal education. In this respect, various paedagogical models in physical education have demonstrated

TABLE 1 Mean values and standard deviation of each dimension.

	2020–2021 season		2021–2022 season		*P*-Value	Effect size
	Mean	Stand. Dev.	Mean	Stand. Dev.		
Personal and team success	3.81	0.63	4.31	0.64	0.001	0.46
Self-fulfilment and pro-social conduct	3.98	0.57	4.22	0.62	0.001	0.26
Sportsmanship and fair play	4.45	0.49	4.32	0.63	0.112	0.09
Personal and group superiority	2.73	0.92	3.46	1.08	0.001	0.39
Health and physical fitness	4.18	0.67	4.39	0.74	0.001	0.21
Peaceful conduct	3.89	0.83	4.12	1.02	0.001	0.18

TABLE 2 Mean values of each dimension, according to country of the social-sports school.

	Spain		Italy		United Kingdom		Romania	
	20–21	21–22	20–21	21–22	20–21	21–22	20–21	21–22
Personal and team success	3.78	3.75	3.95	4.55	3.67	4.67	4.33	4.01
Self-fulfilment	4.14	4.11	4.24	4.44	3.7	4.01	4.48	4.16
Sportsmanship	4.36	4.24	4.54	4.46	4.49	4.26	4.45	4.15
Personal and group superiority	2.83	2.86	3.26	4.12	2.29	3.18	3.77	3.43
Health and physical fitness	4.20	4.04	4.11	4.47	4.11	4.66	4.57	4.45
Peaceful conduct	3.96	4.00	4.17	4.38	3.63	3.94	4.5	3.75

the capacity and effectiveness as regards personal and social development (e.g., Siedentop, 1994; Hellison, 2010). In these studies, the following is observed in particular: the effectiveness of interventions for the psychosocial development of youths (Opstoel et al., 2020), improvements in behaviour related to empathy (Hastie and Sinelnikov, 2006), respect or consideration toward others (Pill, 2008), leadership (Clarke and Quill, 2003) and social relations (Molina et al., 2020). The results of this study confirm that the RMF model makes it possible to export these benefits not only to the area of formal physical education, but also to the field of extracurricular sport. Furthermore, advantages were identified in this research concerning other positive values such as health, peaceful behaviour and sportsmanship. In this respect, the current results reinforce and complete the evidence gathered in recent years about the usefulness of models based on the development of positive values.

However, just like what occurs in other studies that analyse the values of sport in different cultures (e.g., Visek et al., 2010; Jin et al., 2017), the development of these values is seen to be different according to the multicultural environment, dependent on each country. Culture can be defined as a pattern of basic assumptions, shared, invented, discovered or developed by a given group (in this case by a country), which is used to cope with its problems and which works well enough to be considered valid and, therefore, must be taught to new members of the group as the correct way to perceive, think and feel in relation to those problems (Schein, 1991). Expanding on this definition as regards doing and teaching physical activity and sport, sport coaches have beliefs and values that affect their choice of strategies, manners and ways of acting in training and teaching sessions. Any possible educational differences must be considered together with these cultural differences.

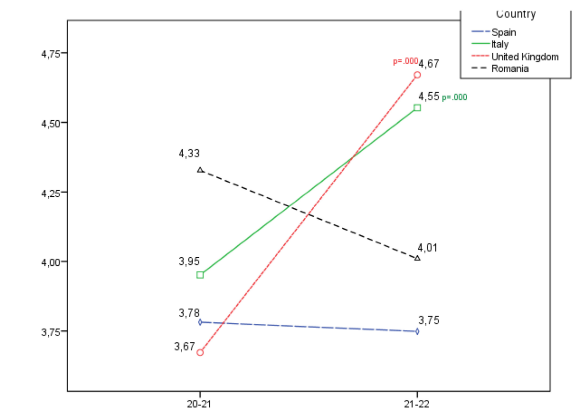

FIGURE 1
Development of the personal and team success dimension, according to country.

The RFM, by means of its education courses, proposes educational activities which are the basis for subsequently implementing its methodological proposals in the various social-sports schools of different countries (Ortega-Vila et al., 2012; Ortega et al., 2021). Even though the education is identical in all of them, the cultural environment has a clear effect on the way in which it is interpreted by coaches, and therefore on its implementation in the sport environment. In this sense, the results of this study show suitable developments in the different countries in almost all dimensions. Having said this, particular emphasis must be put on the improvement of the Personal and team success dimension in schools in the United Kingdom and Italy, and the decrease in values of the Health and physical fitness dimension in

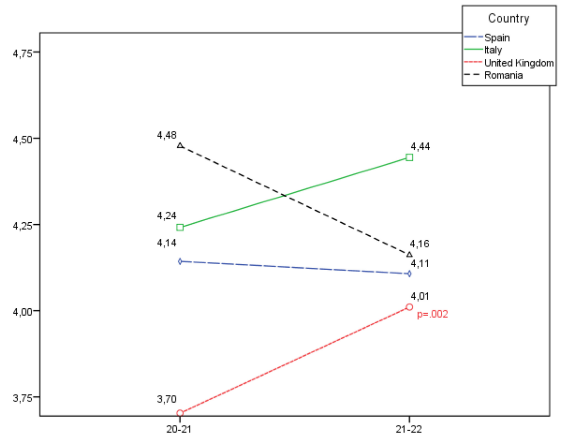

FIGURE 2
Development of the self-fulfilment dimension, according to country.

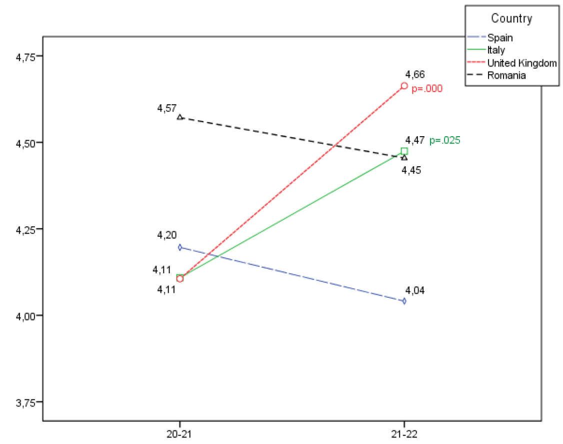

FIGURE 4
Development of the health and physical fitness dimension, according to country.

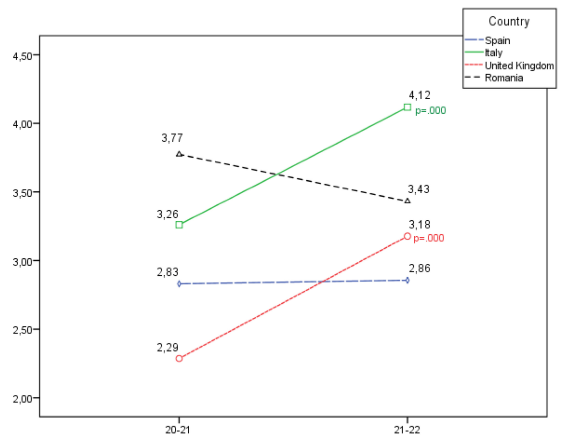

FIGURE 3
Development of the personal and group superiority dimension, according to country.

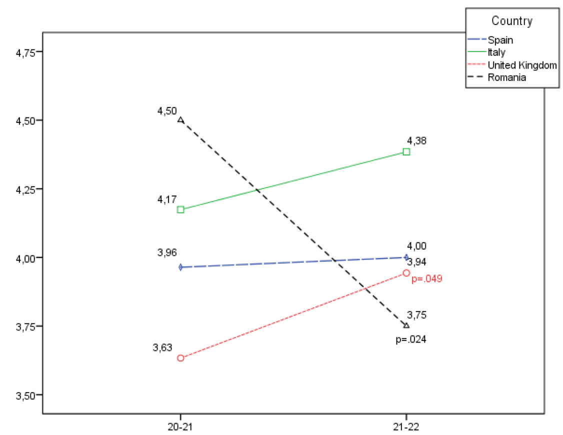

FIGURE 5
Development of the peaceful behaviour dimension, according to country.

Spain and of the Peaceful behaviour dimension in Romania. The high data from the UK and Italy in the Personal and Team Success dimension may be attributed to the perception of both countries as traditional sports powerhouses, evident in their Olympic medal standings. Conversely, Spain has not traditionally been regarded as a nation with notable athletes or physically fit citizens, culturally placing less emphasis on this aspect and prioritising dimensions related to sports values (Serrano-Sanchez et al., 2012). Finally, low scores in the peaceful behaviour dimension in Romania could be a result of cultural and sporting influences from the former Soviet Union, where sporting success took precedence above all else (Parks, 2016).

Thus, it is suggested that the impact of the cultural environment on the development of the various dimensions of the different countries should be analysed, and also that the possibility of including cultural aspects specific to each country in the educational programmes of the RMF itself should be assessed in order to bring the model closer to the cultural needs and distinctive features of each environment.

Regarding the fact that the practical application suggests the necessity to adapt the ongoing RMF training courses conducted in various countries to the psycho-social characteristics of each nation. There is a particular emphasis on raising awareness about values with poorer indicators and generating specific strategies for coaches to implement in their respective environments. The values obtained in this study can serve as a reference so that those responsible for designing materials for the continuous training of RMF coaches can align specific proposals with the authorities in each country. Consequently, using the RMF model as a foundation, minor adaptations will be made in each country to enhance the indicators of values with suboptimal results.

The data of this study reinforce the RMF model as a cross-cutting tool applicable to any kind of cultural context, proving to be an effective alternative to the current sport models which have fed on the new social and political dynamics that are having such a negative effect on the values that have traditionally been associated with sport. Nonetheless, it shall be essential to reinforce the educational process of the model by adapting it to each of the cultural environments where it is implemented, based on the prior analysis of each cultural environment.

5 Conclusion

- The RMF model, a sports model that seeks to improve the values of young people through sport, is a very applicable and effective model in different cultural contexts, although minor adaptations will be necessary in each context.
- The main contributions that are appreciated in the present study of the implementation of the FRM Model are:
    - With respect to the improvement of the value of personal and team success the FRM model gives less importance to the results of the competition, there are no rankings, action is taken when there is too much difference to avoid large differences in the final results, etc.
    - With respect to the improvement of the value of self-realisation and prosocial behaviour in the FRM model, great importance is given to the athletes, both during training and competition, reaching high levels of perceived efficacy and self-realisation. For example, in competitions, many rules are modified to adapt the sport to the psycho-evolutionary characteristics of the young athletes, such as: number of participants, size of the playing field, height of the basket, etc.
    - With respect to the improvement of the value of health, physical fitness and fellowship, the FRM model gives great importance to the improvement of health through specific actions such as strategies to achieve adequate specific warm-ups, promote showers, improve hydration, raise awareness about the importance of changing clothes, eating fruit, or achieving an adequate diet, etc.
    - - Regarding the improvement of the value of Sportsmanship and fair play in the FRM model, the sportiest teams score points for white cards, coaches take advantage of conflicts to educate and promote values, it is important the union within the team and with other teams (the initial warm-up is done together, they reflect at the end of each game).
    - With respect to the improvement of the Personal and group superiority value and the Peaceful behaviour value, the FRM model gives great importance to the need to use dialog to resolve conflicts, so that, both in training and in competition, when a conflict arises, it is necessary to dialog to resolve it, not only individually but group actions are carried out to reflect on what happened and resolve it. For example, after the end of each game, all the players of both teams meet to comment on what happened in the game, highlighting specific actions of other players, commenting on conflictive situations so that they do not happen again, highlighting plays or actions of players, etc.
- The FRM model does something that until now had not been considered in the field of sport, which is to evaluate, plan and sequence in its plan of action in the short, medium and long term as a priority the contents related to values, in addition to other more traditional aspects such as technical, tactical, physical and psychological content.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Comité Investigación Biomédica de Andalucía (PEIBA), Código: 0803-N-20. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

GO-V: Conceptualization, Formal Analysis, Funding acquisition, Project administration, Supervision, Validation, Writing – review and editing. EO-T: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft. FG-F-G: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – review and editing. JR-R: Data curation, Investigation, Methodology, Software, Writing – review and editing. FA-L: Formal Analysis, Investigation, Methodology, Supervision, Writing – review and editing. MA-R: Conceptualization, Formal Analysis, Investigation, Methodology, Supervision, Writing – review and editing.

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References

Babbitt, D. G. (2019). Influences of Eastern and Western Cultures in Sport Coaching Leadership Styles: A Review of the Literature. *Int. J. Coach. Sci.* 13, 18–34.

Balish, S. M., and Caron, J. (2015). Moral foundations, dilemmas, and disengagement in sport: insights from disparate cultures. *Int. J. Sport Psychol.* 46, 371–390. doi: 10.7352/IJSP.2015.46.371

Bhalla, J. A., and Weiss, M. R. (2010). A cross-cultural perspective of parental influence on female adolescents' achievement beliefs and behaviors in sport and school domains. *Res. Q. Exerc. Sport* 81, 494–505. doi: 10.1080/02701367.2010.10599711

Borges, M., Rosado, A., Lobinger, B., Freitas, F., and de Oliveira, R. F. (2022). Cultural intelligence in sport: An examination of football coaches' cross-cultural training needs. *German J. Exerc. Sport Res.* doi: 10.1007/s12662-022-00825-y [Epub ahead of print].

Clarke, G., and Quill, M. (2003). Researching sport education in action: a case study. *Eur. Phys. Educ. Rev.* 9, 253–266.

Ferguson, C. J. (2009). An effect size primer a guide for clinicians and researchers. *Prof. Psychol.* 40, 532–538.

Gutierrez, D., García-López, L. M., Pastor-Vicedo, J. C., Romo-Pérez, V., and Eirín-Nemiña, R. (2017). Percepción del profesorado sobre la contribución, dificultades e importancia de la Educación Física en el enfoque por competencias. *Retos Nuevas Tend. Educ. Física Dep. Recreac.* 31, 34–39.

Hastie, P. A., and Sinelnikov, O. A. (2006). Russian students' participation in and perceptions of a season of Sport Education. *Eur. Phys. Educ. Rev.* 12, 131–150.

Hellison, D. (2010). *Teaching personal and social responsibility through physical activity*. Champaing: Human Kinetics.

Jin, H., Chen, G., and Hee, S. Y. (2017). A cross-cultural study of the sports happiness perception among korean, chinese, and japanese elite swimming athletes. *Int. J. Appl. Sports Sci.* 29, 128–142. doi: 10.24985/ijass.2017.29.2.128

McCarthy, J., Bergholz, L., and Bartlett, M. (2016). *Re-designing youth sport: Change the game*. London: Routledge.

Molina, M., Gutiérrez, D., Segovia, Y., and Hopper, T. F. (2020). El modelo de Educación Deportiva en la escuela rural: amistad, responsabilidad y necesidades psicológicas básicas. *Retos* 38, 291–299.

Niemistö, D., Finni, T., Cantell, M., Korhonen, E., and Sääkslahti, A. (2020). Individual, family, and environmental correlates of motor competence in young children: Regression model analysis of data obtained from two motor tests. *Int. J. Environ. Res. Public Health* 17:2548. doi: 10.3390/ijerph17072548

Opstoel, K., Chapelle, L., Prins, F. J., De Meester, A., Haerens, L., van Tartwijk, J., et al. (2020). Personal and social development in physical education and sports: A review study. *Eur. Phys. Educ. Rev.* 26, 797–813. doi: 10.1177/1356336X19882054

Ortega, G., Abad, M. T., Durán, L. J., Franco, J., Giménez, F. J., Jiménez, P. J., et al. (2015). *Por una Educación REAL: Valores y Deporte Entrenando Fútbol: Enseñando Valores*. Madrid: Fundación Real Madrid.

Ortega, G., Robles, J., Abad, M. T., Durá, L. J., Jiménez, A., and Giménez, F. J. (2021). The Promotion of Values in Young People in Different Contexts of Sport Practice. *Rev. Psicol. Del Dep.* 30, 122–131.

Ortega-Vila, G., Giménez, F. J., Jiménez, A. C., Franco, J., Durán, L. J., and Jiménez, P. J. (2012). *Iniciación al Valorcesto*. Madrid: Fundación Real Madrid.

Parks, J. (2016). *The Olympic Games, the Soviet sports bureaucracy, and the Cold War: Red sport, red tape*. Lanham, MD: Lexington Books.

Pill, S. (2008). A teacher's perceptions of the Sport Education model as an alternative for upper primary school physical education. *ACHPER Austral. Healthy Lifestyles J.* 55, 23–29.

Rivera-Mancebo, M., Gutiérrez, D., Segovia, Y., and Valcárcel, J. V. (2020). Efecto del modelo de Educación Deportiva sobre la conducta prosocial en escolares de Educación Primaria. *Cult. Cien. Dep.* 15, 561–574.

Rodríguez-Muñoz, S., Gallardo, L. O., Moreno Doña, A., and AbarcaSos, A. (2021). Análisis transcultural de los niveles de actividad física y la intención de ser físicamente activo en población adolescente de Chile y España en función de variables sociodemográficas. *Cult. Cien. Dep.* 16, 177–185.

Ruiz, J. V., Ponce de León, A., Valdemoros, M. A., and Sanz, E. (2017). *Cuestionario sobre valores en los deportes de equipo. Educación Secundaria*. Rioja: Universidad de la Rioja.

Sánchez-Gómez, R., Devís-Devís, J., and Navarro-Adelantado, V. (2014). El modelo Teaching Games for Understanding en el contexto internacional y español: una perspectiva histórica. *Ágora Para Educ. Física Dep.* 16, 197–213.

Schein, E. H. (1991). *What is culture*. London: Sage.

Serrano-Sanchez, J. A., Lera-Navarro, A., Dorado-García, C., González-Henriquez, J. J., and Sanchis-Moysi, J. (2012). Contribution of individual and environmental factors to physical activity level among Spanish adults. *PLoS One* 7:e38693. doi: 10.1371/journal.pone.0038693

Shields, D. L., Funk, C. D., and Bredemeier, B. L. (2018). Relationships among moral and contesting variables and prosocial and antisocial behavior in sport. *J. Moral Educ.* 47, 17–33. doi: 10.1080/03057240.2017.1350149

Siedentop, D. (1994). *The sport education model. Sport Education: Quality PE through Positive Sport Experiences*. Champaing: Human Kinetics.

Torstveit, M. K., Johansen, B. T., Haugland, S. H., and Stea, T. H. (2018). Participation in organized sports is associated with decreased likelihood of unhealthy lifestyle habits in adolescents. *Scand. J. Med. Sci. Sports* 28, 2384–2396. doi: 10.1111/sms.13250

Vallence, A. M., Hebert, J., Jespersen, E., Klakk, H., Rexen, C., and Wedderkopp, N. (2019). Childhood motor performance is increased by participation in organized sport: the CHAMPS Study-DK. *Sci. Rep.* 9, 1–8. doi: 10.1038/s41598-019-54879-4

Visek, A. J., Watson, J. C., Hurst, J. R., Maxwell, J. P., and Harris, B. S. (2010). Athletic identity and aggressiveness: A cross-cultural analysis of the athletic identity maintenance model. *Int. J. Sport Exerc. Psychol.* 8, 99–116. doi: 10.1080/1612197X.2010.9671936

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Motor ability development by integrating small-sided games into physical education class

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small-sided game, physical education, fitness, motor ability, team ball sports

Introduction

Approximately 70% of children and adolescents worldwide fail to meet the recommended level of physical activity (He et al., 2021). As obesity-related health issues become increasingly serious, researchers focus on the essential role of physical education (PE) in health promotion for children and adolescents (Hills et al., 2015). PE incorporates a variety of lifetime activities into curricula. School-based interventions are considered an applicable and effective strategy to increase daily PA for children and adolescents, thus leading to a healthy, active lifestyle in adulthood (Bukowsky et al., 2014). Abundant evidence has shown positive effects of PE on physical, affective, social, and cognitive promotion (Bailey, 2006; Donnelly et al., 2016). A recent project provided evidence for the positive influence of a PE program on motor and cognitive development for pre-school children (Battaglia et al., 2020). After 16 weeks of PE classes, significant improvement was identified in locomotor and object control skills. The children also indicated better pre-literacy skills, implying academic success in the future.

Comprehensive motor development in endurance, strength, power, balance, and flexibility is of great importance to children and adolescents (Lubans et al., 2010; van Baak et al., 2021). However, the current PE places a specific attention to quantitative aspects of PA and health-related components of physical fitness such as aerobic fitness, muscular endurance, flexibility, and body composition, but a lack of emphasis on skill-related components in agility, coordination, power, speed, and balance (Myer et al., 2015; Cho et al., 2022; Hao and Yang, 2022; Hastie et al., 2022). Research has shown that PE classes often fail to provide sufficient exercise intensity to induce changes in body tissue composition and physical fitness (Domaradzki et al., 2020). Class activities that incorporate short-term, high-intensity interval training (HIIT) protocols are considered a promising approach to adequate exercise intensity. In addition to the concern with intensity, quality PE requires the class beyond "effective" (Ennis, 2017). By taking advantage of knowledge and theories across disciplinaries, researchers look for novel pedagogical strategies to enhance motivation and facilitate learning (Fang et al., 2022; Pang et al., 2023).

Recently, small-sided games (SSG) have raised a wide interest among PE teachers due to practical considerations. The main reason for the increasing notice on SSG can be attributed to the limited campus space which is particularly evident in Asian countries (Fang et al., 2023). For example, a typical class size of elementary and middle schools in China is about 40. A soccer game in a full field usually accommodates approximate 20 students to play at the same time, leaving the other half of the class not engaged in the game play. Additionally, the large ratio of student to teacher (40:1) also raises a challenge for PE teachers to tack care of the whole class when the students perform individual practice. In this sense, SSG can help PE teachers to organize and manage the class in an efficient manner. A teaching environment requires creative ways to keep appropriate class size in PE (Ennis, 2017). Therefore, the current study aims to lay a theoretical foundation for a wide application of SSG under PE settings by critical analysis on the characteristics and effects of the training modality.

Features of SSG in support of application to PE

As an effective, motivating, and fun exercise that stimulates physiological responses and neuromuscular adjustments, SSG has been widely applied in team ball sports (Ouertatani et al., 2022). The effectiveness of SSG leads to a reasonable implication of applying this PA modality to enhance teaching and learning in PE settings.

Flexible design is a prominent factor to justify successful application of SSG to PE class. Instructors can easily modulate SSG format by the number of players (Moreira et al., 2016), pitch configuration (Chaouachi et al., 2014; Stevens et al., 2016), time, and rules (Clemente et al., 2021a,b) to achieve diverse objectives. Typically, altering the number of players and pitch size is the common approaches to organizing the training modality in practice, which produces significant influences on training intensity (Clemente et al., 2021a,b). Research has shown a positive relationship between relative area and intensity. Reducing the number of players in a constant pitch size increases the relative area for individual players, which stimulates a higher physical load (Moreira et al., 2016).

It is also important to notice the advantage of SSG in replicating the movement patterns of competition (Giménez et al., 2020). This enables players to develop sport-specific fitness and skills required in a high-intensity game situation. Researchers compared soccer players taking 3 vs. 3 SSG with their counterparts performing interval running in an 8-week training program (Radziminski et al., 2013). Changes in VO_{2max} and soccer-specific skills are greater in the SSG group than the interval running group. The prominent improvements are attributed to the increased number of accelerations completed in SSGs compared with the full-size football field (Giménez et al., 2020; Castillo Alvira et al., 2021). Similarly, a systematic review on SSG in volleyball indicated that skill-based conditioning training, which was carried out in the formats of 5 vs. 5, 5 vs. 4, and 5 vs. 3, successfully simulated the high-intensity physiological demand of national-level competition and improved physical fitness in speed, vertical jump, spike jump, agility, upper-body muscular power, and maximal aerobic power (de Oliveira Castro et al., 2021).

High intensity makes SSG a time-efficient training modality for PE (Arslan et al., 2020; de Oliveira Castro et al., 2021; Stojanović et al., 2021). In a typical 45 minutes of PE class, the time for physical activity can be limited excluding the required activities such as warm-up, instructions, and cool down. An alternative to warm-up routines contain a series of high-intensity, short-duration activities inducing a post-activation potentiation effect (Zois et al., 2015). Instructors may consider using SSG as specific conditioning training, which enhances physiological demands in practice (Davids et al., 2013; Mazurek et al., 2018; Arslan et al., 2020; Jurišić et al., 2021).

Due to the intense and intermittent activities in SSG, research evidence has shown advantages of SSG over HIIT. While SSG induces comparable effects on physical performance to HIIT protocols, additional benefit in technical skills has been reported in basketball (Delextrat and Martinez, 2014; Arslan et al., 2022) and soccer (Chaouachi et al., 2014; Arslan et al., 2020). In a meta-analysis on effects of soccer SSG compared with conventional endurance training, no significant difference was identified in endurance performance between the two training groups (Moran et al., 2019). Researchers recommended SSG as a more efficient protocols for simultaneous development of endurance and skills. Despite the benefits of SSG, it is worth noting specific advantages of HIIT in promoting physiological abilities, including maximal oxygen uptake, aerobic performance, linear sprint ability, and repeated sprint ability (Clemente et al., 2021a,b). Researchers and practitioners thus attempt to combine SSG with HIIT for better effects on running performance (Clemente and Sarmento, 2021). Compared with SSG-only approach, the combined protocol increased the acute mechanical load and high-intense running stimuli (Clemente and Sarmento, 2021). Enhanced physical performance in linear sprint, repeated sprint, agility, and countermovement jump have been reported in the combined SSG for young soccer players (Arslan et al., 2021).

Another feature in support of applying SSG to PE is the greater enjoyment than traditional practice. In a study involving youth soccer players, SSG induced greater enjoyment than interval training (Los Arcos et al., 2015). Physical education teachers could use this during specific soccer sessions to maintain a high level of motivation among the students, which induces engagement in class activities (Araújo et al., 2016; Larsen et al., 2018; Sahli et al., 2020). Motivational exercises in PE classes can stimulate physical effort, personal feeling, and enjoyment (Aydi et al., 2023). SSG induces higher physiological responses while maintaining players' motivation. Therefore, SSG increases the amount of time spent in playful and enjoyable activities by allowing learners to experience simulations of competitive team games.

The above analysis identified key features of SSGs to facilitate its application to PE classes, including flexible design, replication of game patterns, high intensity, and enjoyment. By modulating pitch size, player numbers, rules, and play time, instructors can implement the SSG-based class in a time-efficient manner, which effectively enhances strength conditioning and sport-specific skills of the students.

PE class design based on team ball SSG

While the features of SSG imply promising applications to PE class, in this section, further investigations focus on organizations of SSG in team ball sports. Soccer is the mostly studied team ball sport in the existing literature. Organizations of SSG in soccer can be manipulated by variations in pitch area, player number, and rules (Hill-Haas et al., 2011; Halouani et al., 2017). In addition, experienced coaches are skilled at making an adaptive session by altering game rules. A commonly applied approach is to limit the number of touches. Compared with free touch, demanding a maximum of 2–3 touches can increase mental workload as well as intensity during game play (Hill-Haas et al., 2010). Another way to modify game rules is the neutral player. The neutral player transitions to the team in possession to create unbalanced situations between defensive and offensive teams (Mallo and Navarro, 2008). Scoring rules are also determinants of performance in SSG. Researchers have found that the size of goals and presence of goalkeepers influence players' behaviors. In general, the presence of goalkeepers stimulates players' motivation and effort in both attack and defend, which increased the physical load (Dellal et al., 2008).

SSG in basketball is often organized in 2-, 3-, and 4-a-side in half court (Klusemann et al., 2012; Zeng et al., 2021). For example, in a 6-week intervention program, participants underwent 2 vs 2 training in a size of 28m × 7.5m, which induced greater improvement in defensive agility, shooting skills, and upper body power than HIIT (Delextrat and Martinez, 2014). Rule modifications are also applied to organize basketball SSG. In a series of 3 vs. 3 basketball games, specific rules were given to the attacking team, including seven seconds possession and three passes maximum per attack (Camacho et al., 2021). The constraints in time and pass placed a higher demand on cognitive and skill performance, which provide a good example of organizing basketball SSG by rule modifications. Another factor to impose a high level of intensity is the work to rest ratio. In a half court 3 vs. 3 basketball training, researchers designed long-intermittent SSGs which consisted of three 4-min bouts interspersed by 2-min passive recovery, and short-intermittent SSGs which consisted of six 2-min bouts interspersed by 1-min passive recovery (Sansone et al., 2020). The work to rest ratio is a key factor in designing basketball SSG in that shorter regime induces higher technical demands.

SSG in volleyball can be implemented by modified court size. Pekas et al. (2019) conducted 2 vs. 2 in a size of 7m × 3m and 3 vs. 3 in 12m × 6m for young volleyball players. The SSG protocol induced greater improvement in lower body explosive power (i.e., block jump, spike jump, and countermovement jump) than controls. It is interesting to find SSG an effective teaching approach for volleyball novices. Researchers designed 2-a-side in four court configurations which resulted in the area/player ratios of 4.5 m^2 (3.0 m x 3.0 m), 8.0 m^2 (4.0 m x 4.0 m), 10.58 m^2 (4.6 m x 4.6 m), and 13.52 m^2 (5.2 m x 5.2 m). In addition to the benefits in technical skills, tactical behaviors indicated significant improvement after the 3-day training. School-based programs have shown the feasibility of implementing SSG in volleyball PE classes. In an 8-month after-school volleyball program for high school students, significant effects were identified in promoting physical fitness and reducing aggressive behaviors (Trajković et al., 2020).

Conclusion

Evidence-based literature indicated SSG an effective access to high-intensity exercise, suggesting a feasible application of this training approach to PE classes. SSG is characterized by flexible design, replication of game patterns, high intensity, and enjoyment. Integrating SSG into PE classes can effectively stimulate engagement and moderate-to-vigorous physical activities. Based on the characteristics of SSG, PE class design was discussed on soccer, basketball, and volleyball. By modifying pitch size, player numbers, rules, and work to rest ratios, PE teachers can effectively engage students in SSG which promotes physical fitness in concurrent with motor skill learning.

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References

Araújo, R., Mesquita, I., Hastie, P., and Pereira, C. (2016). Students' game performance improvements during a hybrid sport education–step-game-approach volleyball unit. *Eur. Phys. Educ. Rev.* 22, 185–200. doi: 10.1177/1356336X15597927

Arslan, E., Kilit, B., Clemente, F. M., Murawska-Ciałowicz, E., Soylu, Y., Sogut, M., et al. (2022). Effects of small-sided games training versus high-intensity interval training approaches in young basketball players. *Int. J. Environ. Res. Public Health* 19, 2931. doi: 10.3390/ijerph19052931

Arslan, E., Kilit, B., Clemente, F. M., Soylu, Y., Sögüt, M., Badicu, G., et al. (2021). The effects of exercise order on the psychophysiological responses, physical and technical performances of young soccer players: combined small-sided games and high-intensity interval training. *Biology (Basel)* 10, 1180. doi: 10.3390/biology10111180

Arslan, E., Orer, G., and Clemente, F. (2020). Running-based high-intensity interval training vs. small-sided game training programs: effects on the physical performance, psychophysiological responses and technical skills in young soccer players. *Biol. Sport* 37, 165–173. doi: 10.5114/biolsport.2020.94237

Aydi, B., Selmi, O., Marsigliante, S., Souissi, M. A., Souissi, N., and Muscella, A. (2023). Integration of obese children in physical education sessions: an exploratory study. *Children* 10, 133. doi: 10.3390/children10010133

Bailey, R. (2006). Physical education and sport in schools: a review of benefits and outcomes. *J. School Health* 76, 397–401. doi: 10.1111/j.1746-1561.2006.00132.x

Battaglia, G., Giustino, V., Tabacchi, G., Alesi, M., Galassi, C., Modica, C., et al. (2020). Effectiveness of a physical education program on the motor and pre-literacy skills of preschoolers from the training-to-health project: a focus on weight status. *Front. Sports Active Living* 2, 579421. doi: 10.3389/fspor.2020.579421

Bukowsky, M., Faigenbaum, A. D., and Myer, G. D. (2014). FUNdamental Integrative Training (FIT) for physical education. *J. Phys. Educ. Recreat. Dance* 85, 23–30. doi: 10.1080/07303084.2014.926842

Camacho, P., Cruz, D. A., Madinabeitia, I., Giménez, F. J., and Cárdenas, D. (2021). Time constraint increases mental load and influences in the performance in small-sided games in basketball. *Res. Q. Exerc. Sport* 92, 443–452. doi: 10.1080/02701367.2020.1745138

Castillo Alvira, D., Raya González, J., Yanci Irigoyen, J., and Clemente, F. M. (2021). Influence of pitch size on short-term high intensity actions and body impacts in soccer sided games. *J. Hum. Kinet*. 78, 187–196. doi: 10.2478/hukin-2021-0037

Chaouachi, A., Chtara, M., Hammami, R., Chtara, H., Turki, O., and Castagna, C. (2014). Multidirectional sprints and small-sided games training effect on agility and change of direction abilities in youth soccer. *J. Stren. Condition. Res.* 28, 3121–3127. doi: 10.1519/JSC.0000000000000505

Cho, N., Shin, M., and Ahn, H. (2022). Psychosocial characters and their behavioural indexes for evaluation in secondary school physical education classes and sports club activities. *Int. J. Environm. Res. Public Health* 19, 6730. doi: 10.3390/ijerph19116730

Clemente, F. M., Afonso, J., and Sarmento, H. (2021a). Small-sided games: an umbrella review of systematic reviews and meta-analyses. *PloS ONE* 16, e0247067. doi: 10.1371/journal.pone.0247067

Clemente, F. M., Ramirez-Campillo, R., Nakamura, F. Y., and Sarmento, H. (2021b). Effects of high-intensity interval training in men soccer player's physical fitness: a systematic review with meta-analysis of randomized-controlled and non-controlled trials. *J. Sports Sci.* 39, 1202–1222. doi: 10.1080/02640414.2020.1863644

Clemente, F. M., and Sarmento, H. (2021). Combining small-sided soccer games and running-based methods: a systematic review. *Biol. Sport* 38, 617–627. doi: 10.5114/biolsport.2021.102932

Davids, K., Araújo, D., Correia, V., and Vilar, L. (2013). How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exerc. Sport Sci. Rev*. 41, 154–161. doi: 10.1097/JES.0b013e318292f3ec

de Oliveira Castro, H., Laporta, L., Lima, R., Clemente, F., Afonso, J., Aguiar, S., et al. (2021). Small-sided games in volleyball: a systematic review of the state of the art. *Biol. Sport* 39, 995–1010. doi: 10.5114/biolsport.2022.109960

Delextrat, A., and Martinez, A. (2014). Small-sided game training improves aerobic capacity and technical skills in basketball players. *Int. J. Sports Med.* 35, 385–391. doi: 10.1055/s-0033-1349107

Dellal, A., Chamari, K., Pintus, A., Girard, O., Cotte, T., and Keller, D. (2008). Heart rate responses during small-sided games and short intermittent running training in elite soccer players: a comparative study. *J. Stren. Cond. Res.* 22, 1449–1457. doi: 10.1519/JSC.0b013e31817398c6

Domaradzki, J., Cichy, I., Rokita, A., and Popowczak, M. (2020). Effects of Tabata training during physical education classes on body composition, aerobic capacity, and anaerobic performance of under-, normal-and overweight adolescents. *Int. J. Environm. Res. Public Health* 17, 876. doi: 10.3390/ijerph17030876

Donnelly, J., Hillman, C., Castelli, D., Etnier, J., Lee, S., Tomporowski, P., et al. (2016). American College of Sports Medicine position stand. Physical activity, fitness, cognitive function, and academic achievement in children: a systematic review. *Med. Sci. Sports Exerc.* 48, 1197–1222. doi: 10.1249/MSS.0000000000000901

Ennis, C. D. (2017). Educating students for a lifetime of physical activity: enhancing mindfulness, motivation, and meaning. *Res. Quart. Exerc. Sport* 88, 241–250. doi: 10.1080/02701367.2017.1342495

Fang, Q., Xia, Y., Zhang, X., and Huang, F. (2022). Asymmetry of interlimb transfer: pedagogical innovations in physical education. *Front. Psychol.* 13, 1029888. doi: 10.3389/fpsyg.2022.1029888

Fang, Q., Zhang, X., Xia, Y., and Huang, F. (2023). Integrating elastic band into physical education classes to enhance strength training. *Front. Psychol.* 14. doi: 10.3389/fpsyg.2023.1037736

Giménez, J. V., Castellano, J., Lipinska, P., Zasada, M., and Gómez, M.-Á. (2020). Comparison of the physical demands of friendly matches and different types on-field integrated training sessions in professional soccer players. *Int. J. Environm. Res. Public Health* 17, 2904. doi: 10.3390/ijerph17082904

Halouani, J., Chtourou, H., Dellal, A., Chaouachi, A., and Chamari, K. (2017). Soccer small-sided games in young players: rule modification to induce higher physiological responses. *Biology of Sport* 34, 163–168. doi: 10.5114/biolsport.2017.64590

Hao, X., and Yang, Y. (2022). Healthy physical education curriculum model and students' extracurricular sports participation test based on the trans-contextual model of motivation. *BMC Public Health* 22, 1–12. doi: 10.1186/s12889-022-14483-0

Hastie, P. A., Li, P., Liu, H., Zhou, X., and Kong, L. (2022). The impact of sport education on Chinese physical education majors' volleyball content knowledge and performance. *Res. Quart. Exerc. Sport* 1–9. doi: 10.1080/02701367.2022.2026866

He, Z., Wu, H., Yu, F., Fu, J., Sun, S., Huang, T., et al. (2021). Effects of smartphone-based interventions on physical activity in children and adolescents: systematic review and meta-analysis. *JMIR mHealth uHealth* 9, e22601. doi: 10.2196/22601

Hill-Haas, S. V., Coutts, A. J., Dawson, B. T., and Rowsell, G. J. (2010). Time-motion characteristics and physiological responses of small-sided games in elite youth players: the influence of player number and rule changes. *J. Strength Cond. Res.* 24, 2149–2156. doi: 10.1519/JSC.0b013e3181af5265

Hill-Haas, S. V., Dawson, B., Impellizzeri, F. M., and Coutts, A. J. (2011). Physiology of small-sided games training in football: a systematic review. *Sports Med.* 41, 199–220. doi: 10.2165/11539740-000000000-00000

Hills, A. P., Dengel, D. R., and Lubans, D. R. (2015). Supporting public health priorities: recommendations for physical education and physical activity promotion in schools. *Prog Cardiovasc Dis.* 57, 368–374. doi: 10.1016/j.pcad.2014.09.010

Jurišić, M. V., Jakšić, D., Trajković, N., Rakonjac, D., Peulić, J., and Obradović, J. (2021). Effects of small-sided games and high-intensity interval training on physical performance in young female handball players. *Biol. Sport* 38, 359–366. doi: 10.5114/biolsport.2021.99327

Klusemann, M. J., Pyne, D. B., Foster, C., and Drinkwater, E. J. (2012). Optimising technical skills and physical loading in small-sided basketball games. *J. Sports Sci.* 30, 1463–1471. doi: 10.1080/02640414.2012.712714

Larsen, M. N., Nielsen, C. M., Helge, E. W., Madsen, M., Manniche, V., Hansen, L., et al. (2018). Positive effects on bone mineralisation and muscular fitness after 10 months of intense school-based physical training for children aged 8–10 years: the FIT FIRST randomised controlled trial. *Br. J. Sports Med.* 52, 254–260. doi: 10.1136/bjsports-2016-096219

Los Arcos, A., Vázquez, J. S., Martín, J., Lerga, J., Sánchez, F., Villagra, F., et al. (2015). Effects of small-sided games vs. *interval training in aerobic fitness and physical enjoyment in young elite soccer players. PloS ONE* 10, e0137224. doi: 10.1371/journal.pone.0137224

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., and Okely, A. D. (2010). Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Med.* 40, 1019–1035. doi: 10.2165/11536850-000000000-00000

Mallo, J., and Navarro, E. (2008). Physical load imposed on soccer players during small-sided training games. *J. Sports Med. Phys. Fitness* 48, 166–171.

Mazurek, K., Zmijewski, P., Makaruk, H., Mróz, A., Czajkowska, A., Witek, K., et al. (2018). Effects of short-term plyometric training on physical performance in male handball players. *J. Human Kinet.* 63, 137–148. doi: 10.2478/hukin-2018-0014

Moran, J., Blagrove, R. C., Drury, B., Fernandes, J. F. T., Paxton, K., Chaabene, H., et al. (2019). Effects of small-sided games vs. conventional endurance training on endurance performance in male youth soccer players: a meta-analytical comparison. *Sports Med* 49, 731–742. doi: 10.1007/s40279-019-01086-w

Moreira, A., Aoki, M. S., Carling, C., Lopes, R. A. R., de Arruda, A. F. S., Lima, M., et al. (2016). Temporal changes in technical and physical performances during a small-sided game in elite youth soccer players. *Asian J. Sports Med.* 7, 35411. doi: 10.5812/asjsm.35411

Myer, G. D., Faigenbaum, A. D., Edwards, N. M., Clark, J. F., Best, T. M., and Sallis, R. E. (2015). Sixty minutes of what? A developing brain perspective for activating children with an integrative exercise approach. *Br. J. Sports Med.* 49, 1510–1516. doi: 10.1136/bjsports-2014-093661

Ouertatani, Z., Selmi, O., Marsigliante, S., Aydi, B., Hammami, N., and Muscella, A. (2022). Comparison of the physical, physiological, and psychological responses of the high-intensity interval (HIIT) and small-sided games (ssg) training programs in young elite soccer players. *Int. J. Environm. Res. Public Health* 19, 13807. doi: 10.3390/ijerph192113807

Pang, J., Zhao, S., Wang, Y., Wang, Q., and Fang, Q. (2023). Piano practice with emphasis on left hand for right handers: developing pedagogical strategies based on motor control perspectives. *Front. Psychol.* 14, 1124508. doi: 10.3389/fpsyg.2023.1124508

Pekas, D., Mačak, D., and Zobenica, A. K. (2019). Small-sided games are more effective than instructional training for improving vertical jump performance and passing in young volleyball players. *EQOL J.* 11, 13–21. doi: 10.31382/eqol.190602

Radziminski, L., Rompa, P., Barnat, W., Dargiewicz, R., and Jastrzebski, Z. (2013). A comparison of the physiological and technical effects of high-intensity running and small-sided games in young soccer players. *Int. J. Sports Sci. Coach.* 8, 455–466. doi: 10.1260/1747-9541.8.3.455

Sahli, H., Selmi, O., Zghibi, M., Hill, L., Rosemann, T., Knechtle, B., et al. (2020). Effect of the verbal encouragement on psychophysiological and affective responses during small-sided games. *Int. J. Environm. Res. Public Health* 17, 8884. doi: 10.3390/ijerph17238884

Sansone, P., Tessitore, A., Lukonaitiene, I., Paulauskas, H., Tschan, H., and Conte, D. (2020). Technical-tactical profile, perceived exertion, mental demands and enjoyment of different tactical tasks and training regimes in basketball small-sided games. *Biol. Sport* 37, 15–23. doi: 10.5114/biolsport.2020.89937

Stevens, T. G. A., De Ruiter, C. J., Beek, P. J., and Savelsbergh, G. J. P. (2016). Validity and reliability of 6-a-side small-sided game locomotor performance in assessing physical fitness in football players. *J. Sports Sci.* 34, 527–534. doi: 10.1080/02640414.2015.1116709

Stojanović, E., Stojiljković, N., Stanković, R., Scanlan, A. T., Dalbo, V. J., and Milanović, Z. (2021). Recreational basketball small-sided games elicit high-intensity exercise with low perceptual demand. *J. Stren. Condition. Res.* 35, 3151–3157. doi: 10.1519/JSC.0000000000003306

Trajković, N., Pajek, M., Sporiš, G., Petrinović, L., and Bogataj, Š. (2020). Reducing aggression and improving physical fitness in adolescents through an after-school volleyball program. *Front. Psychol.* 11, 2081. doi: 10.3389/fpsyg.2020.02081

van Baak, M. A., Pramono, A., Battista, F., Beaulieu, K., Blundell, J. E., Busetto, L., et al. (2021). Effect of different types of regular exercise on physical fitness in adults with overweight or obesity: systematic review and meta-analyses. *Obesity Rev.* 22, e13239. doi: 10.1111/obr.13239

Zeng, J., Xu, J., Xu, Y., Zhou, W., and Xu, F. (2021). Effects of 4-week small-sided games vs. high-intensity interval training with changes of direction in female collegiate basketball players. *Int. J. Sports Sci. Coach.* 17, 366–375. doi: 10.1177/17479541211032739

Zois, J., Bishop, D., and Aughey, R. (2015). High-intensity warm-ups: effects during subsequent intermittent exercise. *Int. J. Sports Physiol. Perform.* 10, 498–503. doi: 10.1123/ijspp.2014-0338

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Study of the influence of psychological mood on the performance and mental health of athletes in VR-aided basketball training

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The purpose of this study is to determine the influence of psychological mood on the performance and mental health of athletes during VR training. The study involved representatives of both men's and women's basketball teams from universities in China (62 girls and 65 boys, whose average age was 18.2). The participants were divided into 2 groups. Both groups trained regularly, except the experimental group used VR technology, while the control group did not. To study the physical performance of respondents, a complex psychophysiological test was used. The Warwick-Edinburgh Mental Well-Being Scale (WEMWBS) was used to assess the psychological mood and mental health of respondents. The VR training has been proven to increase the psychological attitude of basketball players during the training. Specifically, it has a positive effect on the psychophysiological performance indicators and mental health of athletes. *Prospective research* will be aimed at a comparative study of the impact of VR technology in the training process on the results of basketball players and representatives of other team sports.

KEYWORDS

development of basketball in China, gender characteristics of athletes' performance, mental health of athletes, psychophysiological indicators of athletes, student basketball players, university sports, virtual reality technologies

1 Introduction

Modern education is characterized by the use of virtual learning environments (Shi et al., 2022). Basketball requires an athlete to be tough both physically and mentally, be stress-resistant, and to have the ability to quickly make extraordinary decisions (Shao et al., 2022). The relationship of physical activity with physical and mental health is an interesting topic to study. The importance of the problem of mental health of athletes is evidenced by the increased attention to this issue by the International Society of Sports Psychology. The importance of the athlete's mental health is emphasized as the main resource that determines the athlete's sports career and his life after the end of this career (Henriksen et al., 2020). Undoubtedly, physical culture has long been successfully used to treat somatic diseases and mental disorders, such as anxiety and depression. On the other hand, an increase in physical activity may cause the development of psychological abnormalities. Such abnormalities appear as syndromes of somatoform disorders, overtraining, or excessive physical stress (Liu et al., 2018). This is explained by the stressful nature of VR gaming situations (Brand et al., 2013) and underpins the Mental Health Model (MHM) of sports performance (Raglin, 2001). It is assumed that the basketball training system using VR technologies, ensuring an increase in the effectiveness of training, thereby helps to reduce their stress level, having a positive effect on the mental health of athletes (Ma et al., 2020; Tsai et al., 2021). Therefore, the task of ensuring and supporting the psychological well-being of basketball athletes is more relevant than ever, and it is facilitated by the use of VR technology (Richlan et al., 2022).

The scientific novelty of the study lies in studying the complex effect of VR technology on the physical endurance and mental health of basketball athletes. Moreover, the study justifies the use of VR technology to guide athletes' psychological attitude toward achieving successful results.

The practical significance of the study results is filed as the possibility of using them to develop Chinese basketball and achieve its leading position in the international arena.

2 Literature review

2.1 Theoretical justification of the use of VR technologies for training basketball players

In the present day, basketball is an important part of students' physical education. The use of VR technologies in learning to play basketball is an effective way to foster physical and psychological qualities of athletes (Bedir and Erhan, 2021; Li, 2021). Artificial Intelligence (AI) is seen as an auxiliary technology that can support athletes in the training process (Wei et al., 2021). The use of VR allows to reduce the cognitive anxiety of athletes (Harrison et al., 2021) and helps them learn to control their body, emotions and behavior (Biele, 2022). Ultimately, this leads to better performance (di Fronso et al., 2020) and justifies the importance of gamification both for training athletes (Cmentowski and Krueger, 2021; Uhm et al., 2022) and for solving the sports rehabilitation problems (Yan, 2022). A VR basketball training system allows considering many factors, providing feedback and, thus, improving the efficiency of training (Huang et al., 2019).

2.2 The importance of the psychological attitude of basketball players and the impact of VR training on their performance and mental health

The physical and cognitive health of athletes is a necessary factor in achieving sportsmanship and high performance in basketball (Nanda et al., 2021). Some factors such as cohesion, communicative competence, confidence, attention, anxiety, depression, self-esteem and decision making impact athletes' achievements, and are reflected by the concepts of sports psychology. Additionally, resilience, alertness, and sleep contribute to athletic success, while mental and emotional well-being reduces the risk of injury (Herraro et al., 2020). Mental and physical traumas, as well as stress can cause the rhythm disruption of basketball players' throws (Meng, 2022). For that reason, it is necessary to identify negative factors in order to prevent mental disorders (Sutcliffe and Greenberger, 2020).

The need to deal with stressful factors requires the development of an early monitoring system that would create strategies for managing stress and preventing its negative consequences (Lopes Dos Santos et al., 2020). The use of Athlete Psychological Stress Questionnaire (APSQ) and the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) is recommended (Stewart-Brown et al., 2009; Rice et al., 2020). During training, it is important to consider each athlete's personal psychological profile and psychological skills (Obminski et al., 2020), as it has a significant impact on the performance (Nanda and Dimyati, 2019).

2.3 The use of VR technology in basketball training

Basketball industry uses AI technologies for training athletes, analyzing and predicting the outcome of competitions, as well as for preventing injuries and increasing enjoyment of the game (Li and Xu, 2021). A highly immersive VR basketball training system allows a comprehensive exploration of the intended structure of natural reality. Hence, it improves the effectiveness of teaching basketball tactics and the overall quality of training (Ma et al., 2020; Jin and Zou, 2021; Tsai et al., 2021).

VR provides a solution to applied tactical and technical problems of basketball teaching and self-learning in accordance with educational standards (Bao and Yao, 2021). The result is the higher technical level of basketball training and the comprehensive development of players' abilities (Qingtao, 2020; Wei et al., 2022). Furthermore, the use of VR contributes to fundamental changes that ensure progress in the Chinese basketball industry (Le, 2021; Shi, 2021).

Considering the information stated above, it can be concluded that the study of VR technology and its effect on the psychological attitude and mental health of basketball athletes is a relevant topic aimed at increasing the competitiveness of Chinese basketball at the international level (Wang and Song, 2022).

The purpose of the study is to determine the impact of psychological attitude on the performance and mental health of basketball players during VR training.

The objectives of the study are: (1) to analyze data from scientific literature sources regarding the problem of using VR for basketball development; (2) to conduct a psycho-diagnostic study of the impact of psychological attitude on the performance and mental health of basketball players during VR training.

The research hypothesis holds that the use of VR technology when training basketball players helps improve their psychological attitude to the training process, and has a positive effect on the psycho-physiological performance and mental health of athletes.

3 Materials and methods

3.1 Research design

The study consists of four successive stages. The first stage was to analyze the scientific literature published in the field of basketball development in modern China and the use of VR technology. The impact of online training on the motivation and performance of basketball athletes, their physical and mental health was also analyzed.

Although many researchers are attracted to the topic of the psychological health of basketball players who use VR technology, it remains insufficiently studied. Consequently, this very fact determined the purpose and objectives of the study. During the next stage, the hypothesis of the study was formulated, a sample of respondents was created, and valid research methods were identified. The third stage consisted of conducting an empirical study, statistical processing and analyzing the results. The fourth and final stage concluded the study and determined the prospects for further research. The methodological basis of the study was the philosophical understanding of the person's biopsychosocial nature, the priority role of personal factors in achieving success in sports, as well as understanding The Mental Health Model of sports performance (Raglin, 2001). The said model affirms the presence of a feedback between psychopathology and sports achievements.

3.2 Sample

The sample of respondents was determined by the peculiarities of China's sports policy, focused on basketball development and the search for sports talent through promoting university basketball teams. Both male and female university basketball teams were selected randomly, which made it possible to study the gender aspect of athletes' online training. The study lasted throughout the whole academic semester. Respondents were divided into 2 study groups: experimental group (32 girls and 33 boys, average age 18.7 years) and control group (30 girls and 32 boys, average age 18.9 years).

During the academic semester, the experimental group was taught using VR technologies, while the control group adhered to the traditional method of learning. In the experimental group, VR technologies were used during the training of basketball students. The VireFit program in basketball game mode was used to practice shooting technique, increase reaction speed, develop accuracy and concentration. Immersive training modes using special VR glasses allowed basketball athletes to analyze the game scenario, which contributed to improving their tactical training.

3.3 Study methods

In order to study the physical performance of the respondents, a complex psychophysiological test developed in 1985 by A. A. Nuzhny and R. N. Makarov was used. Since the test allowed us to assess the important psychophysiological parameters of the respondents, it is valid for use in international sports practice (Burov and Erokhina, 2020). The equipment used for the test included 6 foam-covered mats, 2 blue and 2 red 80 cm racks, 3 basketballs of different colors (red, blue, yellow), one 230 cm high gymnastic crossbar, 1 gymnastic bench, 2 wall targets (1×1 m. each), two stopwatches and 11 nameplates with mathematical examples. The athletes were to run the total distance of 57 m.; the lower edge of the targets was at a height of 2 m (Figure 1).

Test execution algorithm: after hearing the "Go" command, the respondent must perform 2 side flips from a standing position on the start line, then 2 somersaults forward with eyes closed, and then continue running forward. During this time the respondent solves the proposed mathematical example. Depending on the result of the solved example, the respondent chooses a basketball of a certain color (numbers from 5 to 10 represent the blue ball, 15 and more is a red ball, any integer is a yellow ball). After choosing the right ball, the respondent dribbles it around the rack No. 1 and then performs 4 throws at the target No. 1, turning 360° after each throw. Next, the respondent dribbles the ball to rack number 2, and, depending on the results of the next solved mathematical example (obtaining an even or odd number), they pass the ball around the red or blue rack. Target #2 is hit by a ricochet off the floor. Then the respondent gives the ball to the researcher, climbs up the inclined gymnastic bench onto the crossbar and jumps feet down into the hole without touching the

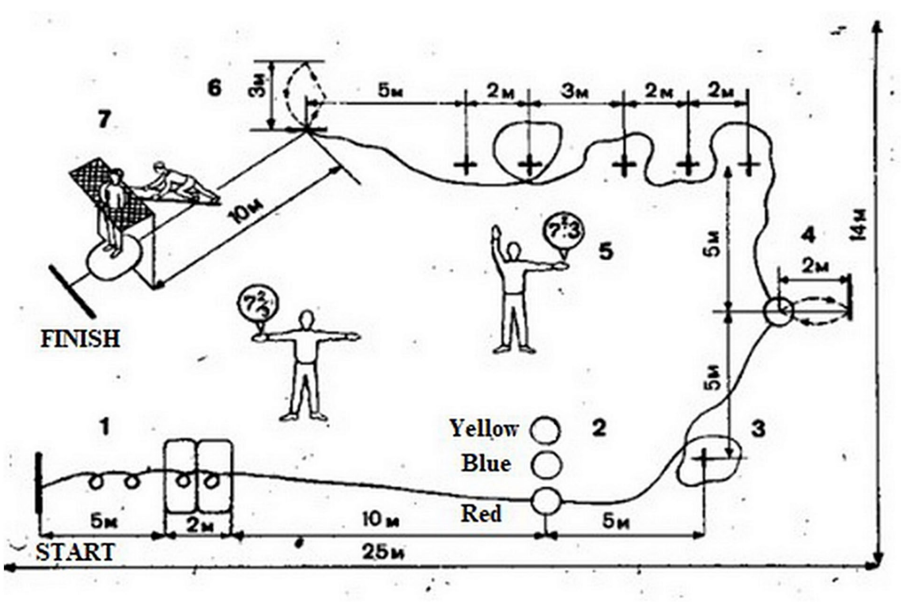

FIGURE 1
Scheme for performing a complex psychophysiological test.

TABLE 1 Criteria for evaluating the complex psychophysiological test results.

No.	Indicators	Checkpoint	External criteria and signs
1.	Vestibular stability	1	Correct body grouping when performing somersaults, taking vertical position, no swaying of the body, rectilinear forward movement
2.	Information perception rate, operational thinking under vestibular irritations	2	Fast digital information reading, correct solution of arithmetic problems
3.	Working memory under vestibular irritations	2	Choosing a ball of the correct color according to the result of the solved arithmetic problem
4.	Movement coordination and accuracy	3	Dribbling and passing around the rack without losing the ball, coordinated work of both hands while dribbling the ball alternately (after passing around the rack)
5.	Fast space orientation under vestibular irritations	4	Precise turns, finding the target and the ball quickly
6.	Ability to extrapolate developments	4	The ball flight time and the time of respondent's turn around their axis are equal; the respondent does not lose the ball
7.	The task switch ability (distributing and shifting attention between one task and another, performing additional work)	5	Passing the ball around the racks in accordance with the correct solution of the arithmetic problem
8.	Ability to quickly change the activity structure	5	The respondent does not hitch and does not lose the ball when assistant coach gives the command to quickly change the direction of passing the ball around the racks
9.	Retaining fine muscle control during emotional arousal and exhaustion	6	Hitting the ball on the target and catching it after the it bounces
10.	Emotional stability	7	No worrying or fussiness, calm facial expressions and gestures when performing the final exercise
11.	Determination	7	Fast non-stop movement to the crossbar and climbing up the gymnastic bench
12.	Confidence	7	No hitches or delays before jumping into the finish line hole

edges with their hands. There are 7 checkpoints for capturing the results throughout the entire distance. The criteria for evaluating the test results are presented in Table 1. The respondents are given 3 attempts to complete the test. If the test is passed, the remaining attempts are not used. The evaluation of the stages (in points) is presented in Table 2.

The psychological attitude and mental health of the respondents were assessed using the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS; Tennant et al., 2007; Stewart-Brown et al., 2009). The methodology scale consists of 14 items that include affective-emotional and cognitive-evaluative aspects and psychological functioning. These items are assessed using a 5-point Likert scale (1 – never, 2 – rarely, 3 – sometimes, 4 – often, 5 – always). The overall minimum score is 14 and the maximum possible score is 70. The higher the score, the higher the level of mental well-being (Tennant et al., 2007).

3.4 Data processing

Statistical processing of data was carried out using Microsoft Excel programs (accumulation, sorting, visualization of data) and the Minitab program (analysis of the results obtained). Current calculations were made using the Social Science Statistics online calculator. To determine the statistical reliability and significance of the study results, Student's t-test was calculated for related and unrelated populations and ANOVA analysis of variance was performed for independent and dependent samples. Cohen's d test was used to assess the actual difference between scores. The relationship between the studied indicators and scales was assessed using the Pearson correlation coefficient. The significance of VR technology as a factor contributing to improved physical performance and improved mental health stability was assessed based on the χ^2 criterion, which was calculated using four-field tables.

TABLE 2 Evaluation of athletes' psycho-physiological qualities on a complex psychophysiological test.

Points	Number of qualities that received a positive mark		
	First attempt	Second attempt	Third attempt
1	-	1–2	1–2
2	1	3	3–4
3	2	4–5	6–8
4	3	6–7	10–12
5	4–5	8–9	-
6	6–7	10–11	-
7	8–9	12	-
8	10–11	-	-
9	12	-	-

Points are given only if the time limit of 70 s is met; otherwise, they are not given at all. The minimum score is 20 and the maximum score is 50.

TABLE 3 Semester dynamics of psychophysiological indicators of female basketball students of the experimental (A—primary study, A1—repeated study) and control (B—primary study, B1—repeated study) groups.

Experimental group								
Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	A	A1						
1	38.2 ± 0.2	44.3 ± 0.1	301.00	0.00	90600.10	0.00	−39.21	−0.99
2	36.4 ± 0.2	45.1 ± 0.3	275.12	0.00	75690.00	0.00	−34.12	−0.99
3	36.9 ± 0.1	45.2 ± 0.4	86.30	0.00	7447.57	0.00	=28.47	−0.99
4	41.2 ± 0.6	46.4 ± 0.2	41.11	0.00	1690.00	0.00	−11.18	−0.98
5	40.4 ± 0.2	44.1 ± 0.4	58.50	0.00	3422.50	0.00	−11.70	−0.99
6	41.5 ± 0.5	48.2 ± 0.3	105.94	0.00	11222.50	0.00	−16.25	−0.99
7	40.8 ± 0.4	46.1 ± 0.5	142.18	0.00	20216.00	0.00	−11.71	−0.99
8	38.2 ± 0.3	43.8 ± 0.2	138.5	0.00	19182.25	0.00	−21.97	−0.99
9	40.2 ± 0.2	44.5 ± 0.3	135.98	0.00	18490.00	0.00	−16.87	−0.99
10	34.3 ± 0.6	43.0 ± 0.2	67.20	0.00	4515.63	0.00	−19.45	−0.99
11	42.1 ± 0.5	45.1 ± 0.3	44.93	0.00	2018.27	0.00	−7.28	−0.96
12	39.1 ± 0.4	44.8 ± 0.2	90.12	0.00	8122.50	0.00	−18.02	−0.99
Total	39.1 ± 0.3	45.1 ± 0.4	189.74	0.00	35000.00	0.00	−16.97	−0.99
Control group								
Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	B	B1						
1	38.3 ± 0.1	42.0 ± 0.4	47.63	0.00	2268.39	0.00	−12.69	−0.99
2	36.8 ± 0.2	40.5 ± 0.8	19.50	0.00	380.28	0.00	−6.35	−0.95
3	36.5 ± 0.5	41.2 ± 0.3	74.31	0.00	552.50	0.00	−11.40	−0.98
4	41.4 ± 0.2	44.0 ± 0.4	41.11	0.00	1690.00	0.00	=8.22	−0.97
5	40.6 ± 0.1	41.5 ± 0.3	13.81	0.00	190.59	0.00	−4.02	−0.90
6	41.9 ± 0.1	44.0 ± 0.2	59.40	0.00	3528.00	0.00	−13.28	−0.99
7	40.6 ± 0.2	43.9 ± 0.3	104.36	0.00	10890.00	0.00	−12.94	−0.99
8	38.0 ± 0.5	41.2 ± 0.4	101.19	0.00	10240.00	0.00	−7.07	−0.96
9	40.3 ± 0.1	42.2 ± 0.3	29.14	0.00	849.41	0.00	−8.50	−0.97
10	34.6 ± 0.2	35.7 ± 0.5	11.60	0.00	134.44	0.00	−2.89	−0.82
11	42.3 ± 0.1	43.4 ± 0.2	1.62	0.18	2.62	0.18	−6.96	−0.96
12	39.0 ± 0.6	41.1 ± 0.3	22.14	0.00	490.00	0.00	−4.43	−0.91
Total	39.2 ± 0.2	41.7 ± 0.4	39.53	0.00	1562.50	0.00	−7.91	−0.97

1, Vestibular stability; 2, Information perception rate, operational thinking under vestibular irritations; 3, Working memory under vestibular irritations; 4, Movement coordination and accuracy; 5, Fast space orientation under vestibular irritations; 6, Ability to extrapolate developments; 7, The task switch ability (distributing and shifting attention between one task and another, performing additional work); 8, Ability to quickly change the activity structure; 9, Retaining fine muscle control during emotional arousal and exhaustion; 10, Emotional stability; 11, Determination; 12, Confidence.

3.5 Ethical issues

Ethical issues were resolved by obtaining permission to conduct the study from the ethics commission and the administrations of the universities. More importantly, the written informed consent to participate in the experiment was obtained from each respondent, ensuring anonymity and confidentiality, academic integrity, and compliance with other bioethical norms. It is worth mentioning that the study did not receive any special funding and there was no conflict of interest. The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki. The research was approved by the local ethics committees of Xinxiang University (Protocol no. 4993 dated from 02/02/2022). Informed consent was signed by parents of the children.

4 Results

Comprehensive psychophysiological testing was carried out twice - at the beginning and at the end of the academic semester. The summarized results of the statistical analysis are presented in Table 3.

TABLE 4 Comparative analysis of the dynamics of indicators of the experimental (A1) and control (B1) groups during repeated research.

Indicators	GPA		Student's t-test	p	ANOVA	p	d Cohen	r
	A1	B1						
1	44.3 ± 0.1	42.0 ± 0.4	17.03	0.00	289.86	0.00	7.89	0.97
2	45.1 ± 0.3	40.5 ± 0.8	16.80	0.00	282.13	0.00	7.61	0.97
3	45.2 ± 0.4	41.2 ± 0.3	24.34	0.00	592.59	0.00	11.31	0.98
4	46.4 ± 0.2	44.0 ± 0.4	16.18	0.00	261.82	0.00	7.59	0.97
5	44.1 ± 0.4	41.5 ± 0.3	15.82	0.00	250.37	0.00	7.35	0.96
6	48.2 ± 0.3	44.0 ± 0.2	34.29	0.00	1176.00	0.00	16.47	0.99
7	46.1 ± 0.5	43.9 ± 0.3	10.98	0.00	120.62	0.00	5.34	0.94
8	43.8 ± 0.2	41.2 ± 0.4	17.53	0.00	307.27	0.00	8.22	0.97
9	44.5 ± 0.3	42.2 ± 0.3	16.26	0.00	264.50	0.00	7.67	0.98
10	43.0 ± 0.2	35.7 ± 0.5	41.46	0.00	1719.03	0.00	19.17	0.99
11	45.1 ± 0.3	43.4 ± 0.2	13.88	0.00	192.67	0.00	6.67	0.96
12	44.8 ± 0.2	41.1 ± 0.3	30.21	0.00	912.67	0.00	14.51	0.99
Total	45.1 ± 0.4	41.7 ± 0.4	18.44	0.00	340.00	0.00	8.5	0.97

1, Vestibular stability; 2, Information perception rate, operational thinking under vestibular irritations; 3, Working memory under vestibular irritations; 4, Movement coordination and accuracy; 5, Fast space orientation under vestibular irritations; 6, Ability to extrapolate developments; 7, The task switch ability (distributing and shifting attention between one task and another, performing additional work); 8, Ability to quickly change the activity structure; 9, Retaining fine muscle control during emotional arousal and exhaustion; 10, Emotional stability; 11, Determination; 12, Confidence.

Initially, the indicators of the experimental and control groups were comparable; there were no statistically or actually significant differences between them ($p > 0.05$; $r < 0.05$). In a repeated study conducted at the end of the academic semester, in both groups—experimental and control—statistically reliable and significant positive psychophysiological dynamics were revealed, which is confirmed by the results of calculating the Student's test and conducting ANOVA analysis of variance ($p < 0.05$). Cohen's d ($r > 0.50$) indicates that there is a real difference between the primary and repeat scores in both groups. However, if during the initial study, no statistically and actually significant differences were revealed between the indicators of the experimental and control groups, then the results of the repeated study indicate that the dynamics of the indicators of the experimental group were statistically and actually more significant compared to the control group, as can be seen from Table 4.

As can be seen from this table, as a result of training conducted during the academic semester, the positive dynamics of psychophysiological indicators of student-athletes in the experimental group who used virtual reality technologies was statistically and actually more significant than that of student-athletes in the control group, which is confirmed by the calculation results Student's t-test ($p < 0.05$), ANOVA analysis of variance ($p < 0.05$), as well as Cohen's d test ($r > 0.50$).

Further, in the course of the study, the features of the dynamics of physical performance of respondents in the experimental and control groups were analyzed depending on the gender factor. Comparative results of the influence of the training method on the psychophysiological indicators of male student-athletes of the experimental and control groups are presented in Table 5.

As can be seen from this table, in both groups—in the experimental group, where virtual reality technologies were used during the training of student-athletes on basketball teams, and in the control group, where virtual reality technologies were not used during the study—the dynamics of male athletes' performance was positive. The advantage of VR training is evidenced by the overall average score of male basketball students, which in the experimental group increased from 40.5 ± 0.4 to 46.2 ± 0.2 points, while in the control group it increased from 40.5 ± 0 0.3 to 43.1 ± 0.2 points. This difference between the results of the primary and repeated measurements was significant and significant both statistically ($p < 0.05$) and factually ($r > 0.50$). However, a comparison of the results of a repeated study of the psychophysiological indicators of male basketball students showed that the observed positive semester dynamics were both statistically and actually more pronounced in the experimental group that used virtual reality technologies for training. The statistical reliability and significance of the identified difference is confirmed by the calculation of Student's t-test ($p < 0.05$), the results of ANOVA analysis of variance ($p < 0.05$) and the values of Cohen's d test ($r > 0.50$).

Comparison of those presented in Table 5 psychophysiological indicators of male basketball students with data from female basketball players showed that the psychophysiological performance of women is slightly lower than that of men. This fact is explained by anatomical and physiological differences between men and women. At the initial assessment, it was 39.1 ± 0.3 points for female basketball students in the experimental group and 40.5 ± 0.4 points for female basketball students in the control group ($p > 0.05$; $r < 0.50$). In a repeated study, the psychophysiological indicators of female basketball players statistically and actually reliably and significantly increased ($p < 0.05$; $r > 0.50$), amounting to 45.1 ± 0.4 points in the experimental group and 42.8 ± 0.6 in the control group. The gender characteristics of the dynamics of psychophysiological indicators of respondents in the experimental group are evidenced by the results of the study presented in Table 6.

Most of the psychophysiological indicators of both male and female basketball students during the initial measurement corresponded to the average level. With repeated measurements, in the control group of basketball athletes who trained in the traditional way, psychophysiological indicators statistically and actually reliably

TABLE 5 Semester dynamics of psychophysiological indicators of male basketball students in the experimental group (Am—primary study, Am1—repeat study) and the control group (Bm—primary study, Bm1—repeat study).

Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Am	Am1						
1	40.2 ± 0.2	45.4 ± 0.1	147.08	0.00	21632.00	0.00	−32.89	−0.99
2	38.6 ± 0.4	44.3 ± 0.2	90.12	0.00	8122.50	0.00	−18.02	−0.99
3	38.7 ± 0.3	44.8 ± 0.6	64.30	0.00	4134.44	0.00	−12.86	−0.99
4	42.1 ± 0.3	46.9 ± 0.1	73.63	0.00	5421.18	0.00	−21.47	−0.99
5	41.3 ± 0.2	45.2 ± 0.3	123.33	0.00	15210.00	0.00	−15.30	−0.99
6	40.1 ± 0.3	48.8 ± 0.2	50.55	0.00	2555.16	0.00	−34.12	−0.99
7	41.9 ± 0.1	47.3 ± 0.2	152.74	0.00	23328.00	0.00	−34.15	−0.99
8	36.9 ± 0.4	44.2 ± 0.2	149.41	0.00	22326.00	0.00	−23.08	−0.99
9	39.4 ± 0.6	44.6 ± 0.4	82.22	0.00	6760.00	0.00	−10.19	−0.98
10	38.2 ± 0.4	45.3 ± 0.2	112.26	0.00	12602.50	0.00	−22.45	−0.99
11	44.2 ± 0.3	48.6 ± 0.2	139.14	0.00	19360.00	0.00	−17.26	−0.99
12	44.4 ± 0.1	48.5 ± 0.1	324.13	0.00	105062.50	0.00	−41.00	−0.99
Total	40.5 ± 0.4	46.2 ± 0.2	90.12	0.00	8122.50	0.00	−18.02	−0.99
Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Bm	Bm1						
1	40.3 ± 0.1	42.2 ± 0.2	53.74	0.00	2888.00	0.00	−12.12	−0.99
2	38.4 ± 0.2	41.4 ± 0.1	84.85	0.00	7200.00	0.00	−18.97	−0.99
3	38.1 ± 0.4	42.5 ± 0.3	139.14	0.00	19360.00	0.00	−12.44	−0.99
4	41.0 ± 0.2	44.8 ± 0.2	4.80	0.00	23.04	0.01	−19.00	−0.99
5	41.6 ± 0.4	42.0 ± 0.2	11.00	0.00	121.00	0.00	−1.26	−0.53
6	40.6 ± 0.2	45.1 ± 0.3	142.30	0.00	20250.00	0.00	−17.65	−0.99
7	41.6 ± 0.4	44.2 ± 0.1	27.03	0.00	730.81	0.00	−8.92	−0.98
8	37.1 ± 0.3	42.0 ± 0.6	51.65	0.00	2667.78	0.00	−10.33	−0.98
9	39.5 ± 0.1	42.0 ± 0.2	70.71	0.00	5000.00	0.00	−15.81	−0.99
10	38.5 ± 0.3	41.2 ± 0.1	41.42	0.00	1715.29	0.00	−12.07	−0.99
11	44.1 ± 0.5	45.0 ± 0.3	14.23	0.00	202.50	0.00	−2.18	−0.74
12	44.6 ± 0.2	45.3 ± 0.2	49.33	0.00	2433.68	0.00	−3.5	−0.87
Total	40.5 ± 0.3	43.1 ± 0.2	82.22	0.00	6760.00	0.00	−10.20	−0.98
Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Am1	Bm1						
1	45.4 ± 0.1	42.2 ± 0.2	41.26	0.00	1701.98	0.00	20.24	0.99
2	44.3 ± 0.2	41.4 ± 0.1	3.02	0.01	9.11	0.02	18.34	0.99
3	44.8 ± 0.6	42.5 ± 0.3	14.70	0.00	216.00	0.00	4.85	0.92
4	46.9 ± 0.1	44.8 ± 0.2	26.56	0.00	705.60	0.00	13.28	0.99
5	45.2 ± 0.3	42.0 ± 0.2	26.13	0.00	682.67	0.00	2.55	0.99
6	48.8 ± 0.2	45.1 ± 0.3	30.21	0.00	912.67	0.00	12.16	0.98
7	47.3 ± 0.2	44.2 ± 0.1	39.99	0.00	1599.00	0.00	19.61	0.99
8	44.2 ± 0.2	42.0 ± 0.6	10.73	0.00	115.24	0.00	4.92	0.93
9	44.6 ± 0.4	42.0 ± 0.2	16.86	0.00	284.09	0.00	8.22	0.97
10	45.3 ± 0.2	41.2 ± 0.1	52.89	0.00	2797.00	0.00	25.93	0.99
11	48.6 ± 0.2	45.0 ± 0.3	29.39	0.00	864.00	0.00	14.12	0.99
12	48.5 ± 0.1	45.3 ± 0.2	41.28	0.00	1703.83	0.00	20.24	0.99
Total	46.2 ± 0.2	43.1 ± 0.2	32.23	0.00	1038.89	0.00	15.50	0.99

1, Vestibular stability; 2, Information perception rate, operational thinking under vestibular irritations; 3, Working memory under vestibular irritations; 4, Movement coordination and accuracy; 5, Fast space orientation under vestibular irritations; 6, Ability to extrapolate developments; 7, The task switch ability (distributing and shifting attention between one task and another, performing additional work); 8, Ability to quickly change the activity structure; 9, Retaining fine muscle control during emotional arousal and exhaustion; 10, Emotional stability; 11, Determination; 12, Confidence.

TABLE 6 Comparison of psychophysiological indicators of student basketball teams depending on the gender factor (student basketball players: Am—primary study; Am1—repeated study; female basketball students: Af—primary study, Af1—repeated study).

Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Am	Af						
1	40.2 ± 0.2	38.2 ± 0.2	23.10	0.00	533.39	0.00	10.00	0.98
2	38.6 ± 0.4	36.4 ± 0.2	14.83	0.00	220.00	0.00	6.96	0.96
3	38.7 ± 0.3	36.9 ± 0.1	1.97	0.04	3.88	0.08	8.05	0.97
4	42.1 ± 0.3	41.2 ± 0.6	2.93	0.01	8.60	0.02	0.00	0.00
5	41.3 ± 0.2	40.4 ± 0.2	8.06	0.00	64.97	0.00	4.5	0.91
6	40.1 ± 0.3	41.5 ± 0.5	−7.38	0.00	54.44	0.00	−3.40	−0.86
7	41.9 ± 0.1	40.8 ± 0.4	8.14	0.00	66.30	0.00	3.77	0.88
8	36.9 ± 0.4	38.2 ± 0.3	−7.91	0.00	62.59	0.00	−3.68	−0.88
9	39.4 ± 0.6	40.2 ± 0.2	−3.90	0.00	15.24	0.00	−1.79	−0.67
10	38.2 ± 0.4	34.3 ± 0.6	16.78	0.00	281.67	0.00	7.65	0.97
11	44.2 ± 0.3	42.1 ± 0.5	10.25	0.00	105.04	0.00	7.00	0.96
12	44.4 ± 0.1	39.1 ± 0.4	29.61	0.00	877.00	0.00	18.18	0.99
Total	40.5 ± 0.4	39.1 ± 0.3	8.52	0.00	72.59	0.00	3.96	0.89
Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Am1	Af1						
1	45.4 ± 0.1	44.3 ± 0.1	5.57	0.00	30.97	0.00	11.00	0.98
2	44.3 ± 0.2	45.1 ± 0.3	−6.53	0.00	42.67	0.00	−3.14	−0.84
3	44.8 ± 0.6	45.2 ± 0.4	−1.72	0.06	2.96	0.12	−0.78	−0.37
4	46.9 ± 0.1	46.4 ± 0.2	6.32	0.00	40.00	0.00	1.71	0.65
5	45.2 ± 0.3	44.1 ± 0.4	6.69	0.00	44.81	0.00	3.11	0.84
6	48.8 ± 0.2	48.2 ± 0.3	4.90	0.00	24.00	0.00	2.35	0.76
7	47.3 ± 0.2	46.1 ± 0.5	1.14	0.14	1.29	0.29	3.15	0.84
8	44.2 ± 0.2	43.8 ± 0.2	4.40	0.00	19.37	0.00	2.00	0.71
9	44.6 ± 0.4	44.5 ± 0.3	0.60	0.29	0.37	0.56	0.28	0.14
10	45.3 ± 0.2	43.0 ± 0.2	3.24	0.01	4.41	0.07	11.50	0.99
11	48.6 ± 0.2	45.1 ± 0.3	28.58	0.00	816.67	0.00	13.73	0.99
12	48.5 ± 0.1	44.8 ± 0.2	46.80	0.00	2190.40	0.00	23.40	0.99
Total	46.2 ± 0.2	45.1 ± 0.4	7.42	0.00	55.00	0.00	3.48	0.87

1, Vestibular stability; 2, Information perception rate, operational thinking under vestibular irritations; 3, Working memory under vestibular irritations; 4, Movement coordination and accuracy; 5, Fast space orientation under vestibular irritations; 6, Ability to extrapolate developments; 7, The task switch ability (distributing and shifting attention between one task and another, performing additional work); 8, Ability to quickly change the activity structure; 9, Retaining fine muscle control during emotional arousal and exhaustion; 10, Emotional stability; 11, Determination; 12, Confidence.

and significantly improved ($p < 0.05$; $r > 0.50$), but continued to remain in the range of average values. At the same time, it was revealed that in most psychophysiological parameters, male basketball athletes were superior to female basketball players. This difference was statistically and factually significant and significant ($p < 0.05$; $r > 0.50$). At the same time, female basketball players were superior to male basketball players in the ability to quickly change the structure of activity (38.2 ± 0.3, 38.2 ± 0.3 and 36.9 ± 0.4 points; $p < 0.05$; $r = -0.88$).

Upon repeated research, the level of psychophysiological indicators of both male and female student-athletes increased significantly and reached a range above average. At the same time, female basketball players outperformed male basketball players in psychophysiological indicators related to the functioning of the vestibular apparatus. However, if the indicators of changes in the speed of information perception, operational thinking during vestibular irritations of female basketball players exceeded the similar indicators of male basketball players statistically and in fact reliably and significantly (45.1 ± 0.3 points vs. 44.3 ± 0.2 points, $p < 0.05$; $r = -0.84$), then the statistical and actual difference in working memory indicators during vestibular stimulation in female basketball players and male basketball players was insignificant (45.2 ± 0.4 points vs. 44.8 ± 0.6 points; $p > 0.05$; $r = -0.37$). VR training resulted in higher development of most psychophysiological qualities in male basketball students than in female basketball students. However, female basketball students had better working memory during vestibular stimulation (45.1 ± 0.3 and 44.8 ± 0.6 points).

Also during this study, the influence of the traditional training method and the training method using virtual reality technologies on

TABLE 7 Semester dynamics of mental health indicators of male basketball students in the experimental group (Am—primary study, Am1—re-study), and male basketball students in the control group (Bm—primary study, Bm1—re-study).

Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Am	Am1						
1	34.4 ± 0.6	44.6 ± 0.4	103.70	0.00	10752.67	0.00	20.00	−0.99
2	35.2 ± 0.3	48.7 ± 0.6	142.30	0.00	20250.00	0.00	−22.5	−0.99
3	26.5 ± 0.3	38.4 ± 0.2	376.31	0.00	141610.00	0.00	−46.68	−0.99
4	30.2 ± 0.4	39.4 ± 0.2	37.16	0.00	1380.63	0.00	−29.09	−0.99
5	40.1 ± 0.3	45.2 ± 0.6	53.76	0.00	2890.00	0.00	−10.75	−0.98
6	35.4 ± 0.2	48.1 ± 0.3	86.00	0.00	7395.16	0.00	−49.81	−0.99
7	33.6 ± 0.4	46.3 ± 0.5	401.61	0.00	161290.00	0.00	−28.05	−0.99
8	34.7 ± 0.3	43.8 ± 0.4	287.77	0.00	82810.00	0.00	−25.74	−0.99
9	31.0 ± 0.2	42.5 ± 0.1	325.27	0.00	105800.00	0.00	−72.73	−0.99
10	33.1 ± 0.5	38.6 ± 0.7	86.96	0.00	7562.50	0.00	−9.04	−0.98
11	36.9 ± 0.1	45.3 ± 0.1	332.04	0.00	110250.00	0.00	−84.00	−0.99
12	42.1 ± 0.3	49.5 ± 0.4	243.01	0.00	54760.00	0.00	−20.93	−0.99
13	43.1 ± 0.2	52.4 ± 0.2	107.59	0.00	11575.12	0.00	−46.50	−0.99
14	38.6 ± 0.4	53.2 ± 0.2	223.95	0.00	50155.29	0.00	−46.17	−0.99
Total	33.2 ± 0.3	45.4 ± 0.4	385.80	0.00	148840.00	0.00	−34.51	−0.99
Indicators	GPA		Student's t-test	*p*	ANOVA	*p*	d Cohen	*r*
	Bm	Bm1						
1	34.3 ± 0.5	36.3 ± 0.2	20.31	0.00	412.63	0.00	−5.25	−0.93
2	35.4 ± 0.1	38.2 ± 0.4	28.94	0.00	837.61	0.00	−9.60	−0.98
3	26.4 ± 0.6	32.1 ± 0.5	180.25	0.00	32490.00	0.00	−10.32	−0.98
4	30.6 ± 0.2	33.5 ± 0.1	82.02	0.00	6728.00	0.00	−18.34	−0.99
5	41.0 ± 0.4	42.8 ± 0.2	28.46	0.00	810.00	0.00	−5.69	−0.94
6	35.6 ± 0.4	42.3 ± 0.1	70.00	0.00	4900.66	0.00	−22.98	−0.99
7	33.2 ± 0.6	39.2 ± 0.4	43.89	0.00	1926.67	0.00	−11.77	−0.99
8	34.9 ± 0.1	38.2 ± 0.5	25.45	0.00	647.83	0.00	−9.15	−0.98
9	31.1 ± 0.4	35.7 ± 0.5	145.46	0.00	21160.00	0.00	−10.16	−0.98
10	33.4 ± 0.2	36.2 ± 0.4	44.27	0.00	1960.00	0.00	−8.85	−0.98
11	37.1 ± 0.3	40.0 ± 0.2	91.72	0.00	8410.00	0.00	−11.37	−0.98
12	42.2 ± 0.1	44.5 ± 0.3	35.28	0.00	1244.71	0.00	−10.29	−0.98
13	43.4 ± 0.1	48.5 ± 0.1	274.74	0.00	75484.57	0.00	−51.00	−0.99
14	38.8 ± 0.2	42.1 ± 0.5	29.64	0.00	2247.62	0.00	−8.67	−0.97
Total	33.6 ± 0.3	36.2 ± 0.4	129.00	0.00	16641.00	0.00	−7.35	−0.96

1, I have been feeling optimistic about the future; 2, I have been feeling useful; 3, I have been feeling relaxed; 4, I have been feeling interested in other people; 5, I have had energy to spare; 6, I have been dealing with problems well; 7, I have been thinking clearly; 8, I have been feeling good about myself; 9, I have been feeling close to other people; 10, I have been feeling confident; 11, I have been able to make up my own mind about things; 12, I have been feeling loved; 13, I have been interested in new things; 14, I have been feeling cheerful.

the mental health indicators of male and female basketball students was compared. In the next Table 7 shows the results of a study of the semester dynamics of the mental health of male basketball students in the experimental group who used VR technology in training, and male basketball students in the control group who trained without using VR technology during the experimental semester. VR technologies.

Comparative statistical analysis presented in Table 7 shows the advantage of training male basketball students using VR technology compared to traditional training. The positive dynamics of mental health are more pronounced in the experimental group (33.2 ± 0.3 and 45.4 ± 0.4 points, $p < 0.05$, $r > 0.50$) compared to the control group (33.6 ± 0.3 and 36.2 ± 0.4 points, $p < 0.05$, $r > 0.50$).

The results of the study of the dynamics of mental health indicators of female basketball students in the experimental group and female basketball students in the control group are presented in Table 8.

The mental health indicators of female student basketball players in the primary study were statistically comparable (34.3 ± 0.4 and 34.3 ± 0.4 points, $p > 0.05$, $r < 0.50$). The second study revealed a statistically and actually significant increase in indicators in the

TABLE 8 Comparative dynamics of mental health indicators of female basketball students in the experimental group (Af—primary study, Af1—re-study), and female basketball students in the control group (Bf—primary study, Bf1—re-study).

Indicators	GPA		Student's t-test	p	ANOVA	p	d Cohen	r
	Af	Af1						
1	34.6 ± 0.2	42.4 ± 0.1	220.62	0.00	48672.00	0.00	−49.33	−0.99
2	32.1 ± 0.3	46.5 ± 0.5	227.68	0.00	51840.00	0.00	−34.93	−0.99
3	28.4 ± 0.6	37.3 ± 0.1	56.01	0.00	3137.03	0.00	−20.69	−0.99
4	33.5 ± 0.3	41.6 ± 0.4	256.14	0.00	65610.00	0.00	−22.91	−0.99
5	38.2 ± 0.4	40.0 ± 0.2	28.46	0.00	810.00	0.00	−5.69	−0.94
6	33.1 ± 0.3	39.3 ± 0.1	120.83	0.00	14599.40	0.00	−27.73	−0.99
7	32.2 ± 0.6	43.2 ± 0.4	40.32	0.00	1625.63	0.00	−21.57	−0.99
8	35.9 ± 0.5	46.0 ± 0.2	126.00	0.00	15876.00	0.00	−26.52	−0.99
9	32.5 ± 0.5	41.4 ± 0.2	93.81	0.00	8801.11	0.00	−23.37	−0.99
10	28.4 ± 0.6	36.9 ± 0.5	268.79	0.00	72250.00	0.00	−15.39	−0.99
11	34.8 ± 0.4	37.1 ± 0.3	72.73	0.00	5290.00	0.00	−6.51	−0.96
12	38.5 ± 0.1	44.3 ± 0.2	183.41	0.00	33640.00	0.00	−36.68	−0.99
13	42.2 ± 0.3	48.6 ± 0.4	202.39	0.00	40960.00	0.00	−18.10	−0.99
14	35.7 ± 0.6	49.2 ± 0.1	84.96	0.00	7217.82	0.00	−31.39	−0.99
Total	34.3 ± 0.4	42.4 ± 0.3	256.14	0.00	65610.00	0.00	−22.91	−0.99
Indicators	GPA		Student's t-test	p	ANOVA	p	d Cohen	r
	Bf	Bf1						
1	34.8 ± 0.4	35.2 ± 0.5	12.65	0.00	160.00	0.00	−0.88	−0.40
2	31.9 ± 0.1	32.0 ± 0.2	2.71	0.05	7.37	0.05	−0.63	−0.30
3	29.1 ± 0.5	30.2 ± 0.3	17.39	0.00	302.50	0.00	−2.67	−0.80
4	33.8 ± 0.4	35.1 ± 0.3	41.11	0.00	1690.00	0.00	−3.68	−0.88
5	38.4 ± 0.1	38.6 ± 0.2	1.26	0.27	1.60	0.27	−1.26	−0.53
6	33.0 ± 0.5	36.1 ± 0.2	32.68	0.00	1067.78	0.00	−8.14	−0.97
7	32.4 ± 0.2	38.3 ± 0.5	62.19	0.00	3867.78	0.00	−15.49	−0.99
8	36.2 ± 0.3	37.4 ± 0.2	61.00	0.00	3721.00	0.00	−4.71	−0.92
9	32.8 ± 0.2	36.9 ± 0.6	47.72	0.00	22777.05	0.00	−9.17	−0.98
10	29.1 ± 0.4	32.6 ± 0.2	86.50	0.00	7482.25	0.00	−11.07	−0.98
11	34.6 ± 0.5	35.8 ± 0.2	12.65	0.00	160.00	0.00	−3.15	−0.84
12	38.2 ± 0.6	40.0 ± 0.4	28.46	0.00	810.00	0.00	−3.53	−0.87
13	42.4 ± 0.1	44.5 ± 0.2	59.40	0.00	3528.00	0.00	−13.28	−0.99
14	35.9 ± 0.5	38.2 ± 0.3	31.03	0.00	962.67	0.00	−5.58	−0.94
Total	34.5 ± 0.3	36.5 ± 0.3	114.73	0.00	13162.58	0.00	−6.67	−0.96

1, I have been feeling optimistic about the future; 2, I have been feeling useful; 3, I have been feeling relaxed; 4, I have been feeling interested in other people; 5, I have had energy to spare; 6, I have been dealing with problems well; 7, I have been thinking clearly; 8, I have been feeling good about myself; 9, I have been feeling close to other people; 10, I have been feeling confident; 11, I have been able to make up my own mind about things; 12, I have been feeling loved; 13, I have been interested in new things; 14, I have been feeling cheerful.

experimental group (42.4 ± 0.3 points vs. 36.5 ± 0.3 in the control group, $p < 0.05$, $r > 0.50$; Table 9).

The primary study revealed that the mental health indicators of female basketball students are statistically and actually reliably and significantly higher than those of male basketball students (34.3 ± 0.4 and 33.2 ± 0.3 points, $p < 0.05$, $r > 0.50$). Training using VR technologies significantly improved mental health indicators of student-athletes of both sexes ($p < 0.05$, $r > 0.50$). However, the mental health indicators of male basketball students increased more significantly, exceeding the same indicators of female basketball students (45.4 ± 0.4 and 42.4 ± 0.3 points, $p < 0.05$, $r > 0.50$).

A direct close correlation was found between the positive psychophysiological dynamics of athletes and their mental health improvement during VR training (Pearson's correlation coefficient for female basketball teams is 0.9994, for male teams—0.9976). A chi-square (χ^2) value in female basketball teams is 6.5971, and in male teams, it equals 5.3455, at $p < 0.05$. When it comes to the mental health of athletes, the χ^2 value equals 11.1604 and 11.2612 at $p < 0.05$. This confirms the assumption that training using virtual reality technologies helps to increase the performance and mental endurance of male and female basketball athletes. After examining these values, we can conclude that the hypothesis of the study is true.

TABLE 9 Comparison of gender characteristics of the dynamics of mental health of basketball students in the experimental group who trained using VR technologies (student basketball players: Am—primary study; Am1—repeated study; female basketball students: Af—primary study, Af1—repeated study).

Indicators	GPA		Student's t-test	p	ANOVA	p	d Cohen	r
	Am	Af						
1	34.4 ± 0.6	34.6 ± 0.2	−0.98	0.18	0.95	0.36	−0.45	−0.22
2	35.2 ± 0.3	32.1 ± 0.3	10.73	0.00	334.26	0.00	10.33	0.98
3	26.5 ± 0.3	28.4 ± 0.6	−8.76	0.00	76.81	0.00	−4.01	−0.89
4	30.2 ± 0.4	33.5 ± 0.3	−20.08	0.00	403.33	0.00	−9.33	−0.98
5	40.1 ± 0.3	38.2 ± 0.4	11.56	0.00	133.70	0.00	5.37	0.94
6	35.4 ± 0.2	33.1 ± 0.3	20.83	0.00	434.06	0.00	9.02	0.98
7	33.6 ± 0.4	32.2 ± 0.6	6.02	0.00	36.30	0.00	2.75	0.81
8	34.7 ± 0.3	35.9 ± 0.5	−6.32	0.00	40.00	0.00	−2.91	−0.82
9	31.0 ± 0.2	32.5 ± 0.5	−8.52	0.00	72.58	0.00	−3.94	−0.89
10	33.1 ± 0.5	28.4 ± 0.6	18.73	0.00	350.63	0.00	8.51	0.97
11	36.9 ± 0.1	34.8 ± 0.4	15.54	0.00	241.64	0.00	7.20	0.96
12	42.1 ± 0.3	38.5 ± 0.1	23.92	0.00	572.30	0.00	16.10	0.99
13	43.1 ± 0.2	42.2 ± 0.3	7.35	0.00	54.00	0.00	3.53	0.87
14	38.6 ± 0.4	35.7 ± 0.6	12.48	0.00	155.74	0.00	5.69	0.94
Total	33.2 ± 0.3	34.3 ± 0.4	−6.69	0.00	44.81	0.00	−3.11	−0.84
Indicators	GPA		Student's t-test	p	ANOVA	p	d Cohen	r
	Am1	Af1						
1	44.6 ± 0.4	42.4 ± 0.1	16.29	0.00	265.21	0.00	7.55	0.97
2	48.7 ± 0.6	46.5 ± 0.5	8.77	0.00	76.83	0.00	3.98	0.89
3	38.4 ± 0.2	37.3 ± 0.1	13.91	0.00	193.60	0.00	6.96	0.96
4	39.4 ± 0.2	41.6 ± 0.4	−14.83	0.00	220.00	0.00	−6.96	−0.96
5	45.2 ± 0.6	40.0 ± 0.2	24.30	0.00	540.41	0.00	11.63	0.99
6	48.1 ± 0.3	39.3 ± 0.1	48.79	0.00	2380.49	0.00	39.35	0.99
7	46.3 ± 0.5	43.2 ± 0.4	14.95	0.00	223.49	0.00	6.85	0.96
8	43.8 ± 0.4	46.0 ± 0.2	−14.83	0.00	220.00	0.00	−6.96	−0.96
9	42.5 ± 0.1	41.4 ± 0.2	13.91	0.00	193.60	0.00	6.96	0.96
10	38.6 ± 0.7	36.9 ± 0.5	6.17	0.00	38.03	0.00	2.79	0.81
11	45.3 ± 0.1	37.1 ± 0.3	77.31	0.00	5976.89	0.00	36.67	0.99
12	49.5 ± 0.4	44.3 ± 0.2	35.06	0.00	1229.09	0.00	16.44	0.99
13	52.4 ± 0.2	48.6 ± 0.4	25.62	0.00	656.36	0.00	12.02	0.99
14	53.2 ± 0.2	49.2 ± 0.1	50.60	0.00	2560.00	0.00	25.30	0.99
Total	45.4 ± 0.4	42.4 ± 0.3	18.26	0.00	333.33	0.00	8.49	0.97

1, I have been feeling optimistic about the future; 2, I have been feeling useful; 3, I have been feeling relaxed; 4, I have been feeling interested in other people; 5, I have had energy to spare; 6, I have been dealing with problems well; 7, I have been thinking clearly; 8, I have been feeling good about myself; 9, I have been feeling close to other people; 10, I have been feeling confident; 11, I have been able to make up my own mind about things; 12, I have been feeling loved; 13, I have been interested in new things; 14, I have been feeling cheerful.

5 Discussion

The development of digital technologies is characterized by their penetration into all spheres of human life. The possibilities of virtual and augmented reality make it possible to create conditions for learning, acquiring and improving the necessary skills. One of the current and promising areas is the use of virtual and augmented reality for training athletes. Despite the fact that the creation of virtual training simulators of sports games is a new direction in the sports industry, their use is becoming increasingly in demand. However, the evidence base for the advantages of VR technologies over traditional training is insufficient, which motivates research in this direction.

One of the factors that determines an athlete's ability to achieve success is performance, which is based on psychological and psychophysiological mechanisms. The sports environment is characterized by increased stress, which also places increased demands on the mental health of athletes.

The popularity of university sports is growing all over the world. In China, this process is characterized by increased attention to the development of basketball, which is spectacular and contributes to the development of communicative competence, stress resistance and other qualities that make basketball an attractive university sport. The active introduction of VR technologies into the training program of basketball athletes raises the problem of their influence on the psychological and physical state of athletes, their performance and mental health.

The use of innovative information technologies and the positive experiences they entail for basketball players in physical training, stress management and psychological adaptation (Post et al., 2020; Morales Téllez et al., 2021; Talha, 2022) make virtual sports an important part of healthy lifestyle (Bum et al., 2018; Chen and Zhu, 2022; Hamad and Jia, 2022). Moreover, such an approach improves the mental health of athletes (Hurley, 2021), trains their perceptual-cognitive skills (Walton et al., 2018) and optimizes performance (Bertollo and Terry, 2021; Siekańska et al., 2021; Richlan et al., 2022). Scientific literature suggests that students experience equal satisfaction from real-life and virtual basketball training (Bum et al., 2018), but AI-assisted training improves the mental health of athletes to a greater extent than traditional gym training (Zhang, 2022).

The results of our study confirm that basketball training using VR technologies contributes to a more significant improvement in the psychophysiological indicators of athletes than traditional training. Also, the use of VR technologies, as shown by the results of our study, has a positive effect on the mental health of basketball athletes.

In addition, the study revealed features of the dynamics of psychophysical indicators and mental health indicators of basketball students depending on the gender factor. It was shown that most psychophysiological qualities were more developed in male basketball students, but female basketball students had better working memory during vestibular stimulation. In addition, training using VR technologies contributed to improvements in mental health indicators, which were more pronounced in male basketball students.

Thus, the evidence presented in our study shows that VR training has more benefits than traditional training and therefore confirms its effectiveness. The results obtained in the study regarding a direct correlation between psychological factors and athlete injuries coincide with the data of scientific literature sources (Leguizamo et al., 2021). Therefore, there is a need for monitoring and analyzing the psychological attitude of athletes in order to improve their future performance (Lochbaum et al., 2021, 2022; Zhou, 2021). Virtual basketball training is more interactive, visual, targeted and effective (Jiang et al., 2022), which is also confirmed by the results of this study.

5.1 Limitations of the study

The limitations of the study include the limited amount of time for conducting the study and a relatively small sample size. These limitations arose because of the peculiarities of forming the university student basketball teams, as well as the complexity of organizing a psychophysiological test. However, due to the randomization procedure and the use of valid research methods, the sample can be considered relevant, and the obtained results are typical for the general population of basketball students.

6 Conclusion

To summarize, this study justifies the use of VR technology as a tool to shape a positive attitude among basketball players and help them achieve success. In addition, the impact of VR training on the psychophysiological indicators and mental health was revealed to vary depending on gender. The study also showed the complex effect of VR technology on the physical endurance and mental health of basketball players. VR technologies managed to increase the psychophysiological indicators to an above-average level, which rarely happened during traditional training.

The positive effect of VR training is proven by the overall average psychophysiological score: 46.2 ± 0.2 points for boys and 45.1 ± 0.4 points for girls in the experimental group; 43.1 ± 0.2 and 41.7 ± 0.4 points, respectively, in the control group. The research hypothesis was confirmed. Such a conclusion is extremely valuable for the development of Chinese basketball industry and it is a huge step toward achieving the leading position of Chinese teams in the international arena.

Future research could compare the performance of basketball players and other team sports representatives when using VR technology in the training process.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Xinxiang University (Protocol no. 4993 dated from 02/02/2022). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

HW: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Bao, H., and Yao, X. (2021). Dynamic 3D image simulation of basketball movement based on embedded system and computer vision. *Microprocess. Microsyst.* 81:103655. doi: 10.1016/j.micpro.2020.103655

Bedir, D., and Erhan, S. E. (2021). The effect of virtual reality technology on the imagery skills and performance of target-based sports athletes. *Front. Psychol.* 11:2073. doi: 10.3389/fpsyg.2020.02073

Bertollo, M., and Terry, P.C. (2021). *Advancements in mental skills training*. London: Routledge.

Biele, C. (2022). "Movement in virtual reality" in *Human movements in human-computer interaction (HCI)*. ed. C. Biele (Cham: Springer), 75–87.

Brand, R., Wolff, W., and Hoyer, J. (2013). Psychological symptoms and chronic mood in representative samples of elite student-athletes, deselected student-athletes and comparison students. *Sch. Ment. Heal.* 5, 166–174. doi: 10.1007/s12310-012-9095-8

Bum, C. H., Mahoney, T. Q., and Choi, C. (2018). A comparative analysis of satisfaction and sustainable participation in actual leisure sports and virtual reality leisure sports. *Sustain. For.* 10:3475. doi: 10.3390/su10103475

Burov, A.E., and Erokhina, O.A. (2020). *Diagnostics and assessment of professionally important qualities in the practice of professionally applied physical culture: A scientific and practical guide*. Moscow: Sreda Publishing House.

Chen, L., and Zhu, H. (2022). Importance of national fitness sports relying on virtual reality technology in the development of sports economy. *Comput. Intell. Neurosci.* 2022:4128981. doi: 10.1155/2022/4128981

Cmentowski, S., and Krueger, J. (2021). "Exploring the potential of vertical jump training in virtual reality" in *Extended abstracts of the 2021 annual symposium on computer-human interaction in play*. eds. G. Wallner, A. Meschtscherjakov, M. Birk, J. Iacovides and M. McEwan (New York, NY: Association for Computing Machinery), 179–185.

di Fronso, S., Werthner, P., Christie, S., and Bertollo, M. (2020). "Using technology for self-regulation in sport" in *Feelings in sport*. eds. M. C. Ruiz and C. Robaz (New York: Routledge), 178–186.

Hamad, A., and Jia, B. (2022). How virtual reality technology has changed our lives: an overview of the current and potential applications and limitations. *Int. J. Environ. Res. Public Health* 19:11278. doi: 10.3390/ijerph191811278

Harrison, K., Potts, E., King, A. C., and Braun-Trocchio, R. (2021). The effectiveness of virtual reality on anxiety and performance in female soccer players. *Sports* 9:167. doi: 10.3390/sports9120167

Henriksen, K., Schinke, R., Moesch, K., McCann, S., Parham, W. D., Larsen, C. H., et al. (2020). Consensus statement on improving the mental health of high performance athletes. *Int. J. Sport Exerc. Psychol.* 18, 553–560. doi: 10.1080/1612197X.2019.1570473

Herraro, C. P., Jejurikar, N., and Carter, C. W. (2020). The psychology of the female athlete: how mental health and wellness mediate sports performance, injury and recovery. *Ann. Jt.* 6:38. doi: 10.21037/aoj-20-53

Huang, C., Zhang, Y., Zhu, C., Zhang, C., and Meng, H. (2019). Chinese sports basketball teaching tactics training system combined with multimedia interactive model and virtual reality technology. *Multimed. Tools Appl.* 82:25491. doi: 10.1007/s11042-019-7298-9

Hurley, O. A. (2021). Sport cyberpsychology in action during the COVID-19 pandemic (opportunities, challenges, and future possibilities): a narrative review. *Front. Psychol.* 12:621283. doi: 10.3389/fpsyg.2021.621283

Jiang, J., Wu, S., and Zhang, S. (2022). Design and research of VR basketball teaching system based on embedded intelligent sensor. *J. Environ. Public Health* 2022:3688596. doi: 10.1155/2022/3688596

Jin, Z., and Zou, W. (2021). Research on the design of online teaching system of basketball basic technology. *J. Phys. Conf. Ser.* 1992:032080. doi: 10.1088/1742-6596/1992/3/032080

Le, Z. (2021). Research on the application of computer virtual technology in basketball sports training. *J. Phys. Conf. Ser.* 1915:032071. doi: 10.1088/1742-6596/1915/3/032071

Leguizamo, F., Olmedilla, A., Núñez, A., Verdaguer, F. J. P., Gómez-Espejo, V., Ruiz-Barquín, R., et al. (2021). Personality, coping strategies, and mental health in high-performance athletes during confinement derived from the COVID-19 pandemic. *Front. Public Health* 8:561198. doi: 10.3389/fpubh.2020.561198

Li, H. (2021). Research on basketball sports training based on virtual reality technology. *J. Phys. Conf. Ser.* 1992:032047. doi: 10.1088/1742-6596/1992/3/032047

Li, B., and Xu, X. (2021). Application of artificial intelligence in basketball sport. *J. Educ. Health Sport* 11, 54–67. doi: 10.12775/jehs.2021.11.07.005

Liu, H., Li, Y., Zhao, S., Jiao, M., Lu, Y., Liu, J., et al. (2018). Perceptions of patient safety culture among medical students: a cross-sectional investigation in Heilongjiang Province, China. *BMJ Open* 8:e020200. doi: 10.1136/bmjopen-2017-020200

Lochbaum, M., Stoner, E., Hefner, T., Cooper, S., Lane, A. M., and Terry, P. C. (2022). Sport psychology and performance meta-analyses: a systematic review of the literature. *PLoS One* 17:e0263408. doi: 10.1371/journal.pone.0263408

Lochbaum, M., Zanatta, T., Kirschling, D., and May, E. (2021). The profile of moods states and athletic performance: a meta-analysis of published studies. *Eur. J. Investig. Health Psychol. Educ.* 11, 50–70. doi: 10.3390/ejihpe11010005

Lopes Dos Santos, M., Uftring, M., Stahl, C. A., Lockie, R. G., Alvar, B., Mann, J. B., et al. (2020). Stress in academic and athletic performance in collegiate athletes: a narrative review of sources and monitoring strategies. *Front. Sports Act. Living* 2:42. doi: 10.3389/fspor.2020.00042

Ma, Z., Wang, F., and Liu, S. (2020). Feasibility analysis of VR technology in basketball training. *IEEE Access.* doi: 10.1109/ACCESS.2020.3019810

Meng, Q. (2022). Psychological analysis of athletes during basketball games from the perspective of deep learning. *Mob. Inf. Syst.* 2022, 1–9. doi: 10.1155/2022/4319437

Morales Téllez, A., Tentori, M. E., and Castro, L. A. (2021). "Stress management training in athletes: design considerations for VR biofeedback systems" in *In 8th Mexican conference on human-computer interaction*. eds. V. Meza, O. Mayora, K. Caro and D. Cruz-Sandoval (New York, NY: Association for Computing Machinery), 1–3.

Nanda, F. A., and Dimyati, D. (2019). The psychological skills of basketball athletes: are there any differences based on the playing position? *J. Keolahragaan* 7, 74–82. doi: 10.21831/jk.v7i1.26360

Nanda, F. A., Novriansyah, N., Nugroho, M. D., Fajaruddin, S., Utama, M. B. R., Burhaein, E., et al. (2021). Psychological skills of basketball athletes by perspektive gender: study Indonesian athletes in Asian games XVIII. *Sport Sci.* 15, 158–167.

Obminski, Z., Mroczkowska, H., Jagiello, M., and Litwiniuk, A. (2020). Sex-and sport related differences in the personality traits students in volleyball, basketball and judo athletes. *Phys. Educ. Stud.* 24, 304–311. doi: 10.15561/20755279.2020.0601

Post, E. G., Biese, K. M., Schaefer, D. A., Watson, A. M., McGuine, T. A., Brooks, M. A., et al. (2020). Sport-specific associations of specialization and sex with overuse injury in youth athletes. *Sports Health* 12, 36–42. doi: 10.1177/1941738119886855

Qingtao, Z. (2020). Analysis and research on the combination of virtual reality technology (VR) and college sports training. *J. Phys. Conf. Ser.* 1486:052011. doi: 10.1088/1742-6596/1486/5/052011

Raglin, J. S. (2001). Psychological factors in sport performance. *Sports Med.* 31, 875–890. doi: 10.2165/00007256-200131120-00004

Rice, S. M., Parker, A. G., Mawren, D., Clifton, P., Harcourt, P., Lloyd, M., et al. (2020). Preliminary psychometric validation of a brief screening tool for athlete mental health among male elite athletes: the athlete psychological strain questionnaire. *Int. J. Sport Exerc. Psychol.* 18, 850–865. doi: 10.1080/1612197X.2019.1611900

Richlan, F., Weiß, M., Braid, J., and Kastner, P. (2022). Virtual training, real effects: a systematic literature review on sports performance enhancement through interventions in virtual reality. *PsyArXiv.* doi: 10.31234/osf.io/ckgm2

Shao, Z., Bezmylov, M. M., and Shynkaruk, O. A. (2022). Individual characteristics of physical and mental development and their connection with regular physical exercises when playing basketball. *Curr. Psychol.* 42, 1–10. doi: 10.1007/s12144-022-03692-w

Shi, F. (2021). Research on the application of computer virtual technology in basketball teaching. *J. Phys. Conf. Ser.* 1915:032070. doi: 10.1088/1742-6596/1915/3/032070

Shi, A., Wang, Y., and Ding, N. (2022). The effect of game–based immersive virtual reality learning environment on learning outcomes: designing an intrinsic integrated educational game for pre–class learning. *Interact. Learn. Environ.* 30, 721–734. doi: 10.1080/10494820.2019.1681467

Siekańska, M., Bondár, R. Z., di Fronso, S., Blecharz, J., and Bertollo, M. (2021). Integrating technology in psychological skills training for performance optimization in elite athletes: a systematic review. *Psychol. Sport Exerc.* 57:102008. doi: 10.1016/j.psychsport.2021.102008

Stewart-Brown, S., Tennant, A., Tennant, R., Platt, S., Parkinson, J., and Weich, S. (2009). Internal construct validity of the Warwick-Edinburgh mental well-being scale (WEMWBS): a Rasch analysis using data from the Scottish health education population survey. *Health Qual. Life Outcomes* 7:15. doi: 10.1186/1477-7525-7-15

Sutcliffe, J. H., and Greenberger, P. A. (2020). Identifying psychological difficulties in college athletes. *J Allergy Clin Immunol Pract* 8, 2216–2219. doi: 10.1016/j.jaip.2020.03.006

Talha, M. (2022). Research methods and information technology applications in movement science and sport psychology. *Rev. de Psicol. del Deporte* 31, 123–131.

Tennant, R., Hiller, L., Fishwick, R., Platt, S., Joseph, S., Weich, S., et al. (2007). The Warwick-Edinburgh mental well-being scale (WEMWBS): development and UK validation. *WEMWBS* 5:63. doi: 10.1186/1477-7525-5-63

Tsai, W. L., Su, L. W., Ko, T. Y., Pan, T. Y., and Hu, M. C. (2021). Feasibility study on using AI and VR for decision-making training of basketball players. *IEEE Trans. Learn. Technol.* 14, 754–762. doi: 10.1109/TLT.2022.3145093

Uhm, J. P., Kim, S., and Lee, H. W. (2022). Stimulating suspense in gamified virtual reality sports: effect on flow, fun, and behavioral intention. *Int. J. Hum.-Comput. Interact.* 39, 3846–3858. doi: 10.1080/10447318.2022.2107782

Walton, C. C., Keegan, R. J., Martin, M., and Hallock, H. (2018). The potential role for cognitive training in sport: more research needed. *Front. Psychol.* 9:1121. doi: 10.3389/fpsyg.2018.01121

Wang, J., and Song, X. (2022). Development status and influencing factors of competitive basketball management system under the background of deep learning. *Comput. Intell. Neurosci.* 2022:5659467. doi: 10.1155/2022/5659467

Wei, S., Huang, P., Li, R., Liu, Z., and Zou, Y. (2021). Exploring the application of artificial intelligence in sports training: a case study approach. *Complexity* 2021, 1–8. doi: 10.1155/2021/4658937

Wei, W., Qin, Z., Yan, B., and Wang, Q. (2022). Application effect of motion capture technology in basketball resistance training and shooting hit rate in immersive virtual reality environment. *Comput. Intell. Neurosci.* 2022:4584980. doi: 10.1155/2022/4584980

Yan, H. (2022). Construction and application of virtual reality-based sports rehabilitation training program. *Occup. Ther. Int.* 2022:4364360. doi: 10.1155/2022/4364360

Zhang, R. (2022). Impact analysis of basketball exercise strength based on machine learning in the mental health of college students. *Comput. Intell. Neurosci.* 2022:9628446. doi: 10.1155/2022/9628446

Zhou, L. (2021). Research on basketball basic technology design based on computer online teaching system. *J. Phys. Conf. Ser.* 1992:032034. doi: 10.1088/1742-6596/1992/3/032034

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Artistic sports activities effectiveness for enhancing students' academic performance among left-behind children: mediating effects of loneliness

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Introduction: Numerous studies within the school and academic contexts have underscored the profound impact of psychometric variables such as academic self-efficacy, self-esteem, and loneliness on academic achievement among children. Although physical activities and dance practices are known to bolster academic self-efficacy and enhance academic outcomes, the effect of Artistic Sports Activities on these psychological determinants among left-behind children (LBC) in rural schools remains underexplored.

Method: This study was conducted from September 2020 to January 2022 among 405 LBCs aged 9 to 13 from six randomly selected primary schools in Hunan Province, China. Schools were chosen in collaboration with the Hunan Women and Children's Federation, ensuring informed consent through stakeholder informational sessions. The study employed rigorous sampling and data analysis methods, including the Shapiro–Wilk test for normal distribution and Cronbach's alpha for reliability, alongside Pearson correlation, independent and paired t-tests, and multiple linear regression analyses to investigate the effects of Artistic Sports Activities on psychometric variables and academic performance among LBCs. Data collection involved standardized questionnaires assessing academic self-efficacy, self-esteem, and loneliness before and after intervention.

Results: Findings indicate that Artistic Sports Activities significantly improved academic self-efficacy and self-esteem and reduced loneliness, leading to enhanced academic performance. Notably, loneliness was identified as mediating the relationship between academic self-efficacy and self-esteem among LBCs.

Discussion: The findings highlight the critical role of integrating Artistic Sports Activities in educational frameworks to bolster psychological and academic outcomes for LBCs. The study reveals the intricate interplay between loneliness, self-esteem, and academic self-efficacy, underscoring the necessity for targeted educational interventions.

KEYWORDS

artistic sports activities, left-behind children, academic performance, student's academic self-efficacy, self-esteem, loneliness

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1 Introduction

In China, large numbers of rural residents are migrating to urban areas for job opportunities (Gu, 2022), resulting in the emergence of Left-Behind Children (LBC), kids under 18 with one or both parents working away, leaving them with grandparents or local communities (Chen et al., 2022). The school environments of these LBCs reflect significant challenges rooted in psychosocial factors. Extended parental absence correlates with adverse educational outcomes such as increased school dropouts (Li and Hu, 2021), bullying in school (Zhang et al., 2022), high suicidal thoughts (Zhou et al., 2022), aggressive behaviors in school (Yu et al., 2022), higher levels of antisocial behavior (Liu et al., 2022), loneliness (Wang Q. et al., 2021), reduced academic performance (Mao et al., 2020), lower self-esteem (Zhou et al., 2022) and lower self-efficacy (Liang et al., 2018).

From a the school and academic contexts, it's imperative to understand the interplay of psychometric variables like academic self-efficacy, self-esteem, and loneliness in shaping a student's educational journey (Neroni et al., 2022). As shown in various studies, these psychological determinants are pivotal in predicting academic outcomes. For instance, Bhatt and Bahadur (2018) highlighted that higher levels of academic self-efficacy among students increased motivation and resulted in higher academic performance, while Huang (2011) found a positive association between self-esteem and academic performance, as well as Honicke and Broadbent (2016) emphasized that academic self-efficacy has a strong moderated positive correlated with academic performance. Moreover, the adverse effects of loneliness on students' well-being and academic progress have been documented by Qualter et al. (2015). In a pivotal finding, Zhou et al. (2023) discovered that improving self-esteem can increase academic self-efficacy, thereby enhancing the academic performance of LBCs. These insights underscore the significance of addressing psychometric variables in educational settings to foster a conducive learning environment (Table 1).

Within the school and academic contexts, the triad of academic self-efficacy, self-esteem, and loneliness has been recognized as crucial determinants of students' academic performance. However, the intricate relationships among these psychometric variables, especially the mediating role of loneliness between self-esteem and academic self-efficacy, remain uncharted for left-behind children (LBCs).

According to Bandura's Social Cognitive Theory (Bandura, 2012), individuals' mental states are influenced by combining self-influence factors and social systems (Bandura, 1977). Regarding self-influence factors, Bandura's Social Cognitive Theory highlights the significance of self-efficacy, which refers to an individual's belief in their capabilities to organize and execute actions to achieve desired results (Bandura, 1997). In the academic context, researchers often use academic self-efficacy to mean the level of self-efficacy that learners judge in themselves about their abilities to achieve educational goals (Morales-Rodríguez and Pérez-Mármol, 2019). Affuso et al. (2022) highlighting that high self-efficacy improves children's academic performance. Another self-influence factor is self-esteem (Bhatt and Bahadur, 2018), which is included in Abraham Maslow's theory of "Maslow's Hierarchy of Needs." Maslow and Lewis (1987) suggest that if self-esteem needs are unmet, individuals cannot grow, develop, or achieve their self-goals, including children's academic performance (Noronha et al., 2018).

When considering the social systems, Bronfenbrenner's ecological systems theory (Bronfenbrenner, 1992) underscores the family and peers' pivotal roles in influencing children's development, especially in adversities (Ren and Li, 2020). This emphasis is critical when a child's primary microsystem fails to provide the needed psychological support, spotlighting the importance of other microsystems in such instances (Hertler et al., 2018). For children from left-behind backgrounds (LBCs), the absence of parental and peer support markedly increases their risk of social anxiety and loneliness (Cavanaugh and Buehler, 2016). Theoretical insights suggest that the quality of interactions within these social systems–family and peers–can profoundly affect self-influencing factors, such as self-esteem and academic self-efficacy. Loneliness, significantly shaped by these interactions, emerges as a critical factor impacted by family and peer dynamics. Meanwhile, Fuentealba-Urra et al. (2022) highlighted the importance of considering the relationship between the type and context of physical activity in adolescents. This underscores the theory's broader implication that nurturing relationships in these systems can mitigate negative emotional states and enhance psychological resilience in children.

In the diverse range of school-based activities, Wang et al. (2024) revealed that school-based physical activity significantly influences children's self-identity and reduces social anxiety, also artistic sports activities have uniquely beneficial, which include artistic elements like music, choreography, and costumes, they aim to boost the sport's esthetic value and provide an audio-visual and postural expression of fitness and esthetic appreciation (Qi, 2018). This blend distinguishes

TABLE 1 Overview of psychometric variables influencing academic performance.

Psychometric Variable	Definition	Influence on academic performance
Students' Academic Self-Efficacy	A student's belief in their ability to meet the demands of their academic environment (Fife et al., 2011).	Significant influence on predicting academic resilience (Bandura, 1997). Facilitates the development of academic goal-setting skills (Locke and Latham, 2002) and impacts academic performance (Honicke and Broadbent, 2016).
Self-Esteem	A psychological state corresponds to a sense of integrity in understanding one's capabilities and value (Saha, 2018).	Mediates the relationship between parent–child relationships and academic stress (Mulyadi et al., 2016). Strongly correlates with academic performance and teacher support (Liu et al., 2019).
Loneliness	An unpleasant emotion of discrepancy between desired and experienced interpersonal relationships (Perlman and Peplau, 1982), is typically experienced by LBC (Shen et al., 2015).	Associated with a lack of family connections (Cacioppo et al., 2015), and correlated with individual problems among LBC, such as emotional problems (e.g., social anxiety) (Li et al., 2020), psychological problems (e.g., self-esteem) (Wei and Huang, 2019), and education-related problems (e.g., student academic performance or achievement) (Wang Y. et al., 2021).

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artistic sports from their non-artistic counterparts by fostering physical and mental growth, offering a distinctive pathway to bolster children's psychological health (Zhang, 2009). Jianshe Zhou (2020) notes the unique potential of these activities, beyond what conventional activities can achieve, to fortify psychological well-being. Disciplines such as figure skating, aerobic gymnastics, dance sports, rhythmic gymnastics, and synchronized swimming (Qi, 2018) play pivotal roles. Specifically, Latino Dance has been found to reduce loneliness (Hong-gang Shan and Yu, 2011) and significantly enhance academic self-efficacy (Zhou et al., 2023), diminish anxiety (Shan and Yu, 2011), lessen self-accusation tendencies and improve both self-efficacy (Hui and Junyu, 2014) and self-esteem among LBC students (Zhou et al., 2023).

Therefore, this study aims to investigate whether artistic sports activities interventions (Aerobic Gymnastics and Latin American dance) can enhance the academic performance of LBC (improve students' academic self-efficacy and self-esteem and reduce loneliness). Four research hypotheses will be verified in this research: Hypothesis 1 (H1): Artistic Sports Activities interventions, specifically Aerobic Gymnastics and Latin American dance, will increase academic self-efficacy among LBCs. Hypothesis 2 (H2): Participation in Artistic Sports Activities will improve self-esteem levels among LBCs. Hypothesis 3 (H3): Engaging in Artistic Sports Activities will reduce feelings of loneliness among LBCs. Hypothesis 4 (H4): Loneliness will mediate the relationship between academic self-efficacy and self-esteem among LBCs, such that reduced loneliness associated with participation in Artistic Sports Activities will improve both self-esteem and academic self-efficacy.

2 Methods

2.1 Design

This study adopted a research design to investigate the impact of physical education (PE) on the holistic development of left-behind children (LBCs) in primary schools across Hunan Province, Southern China. The suitability of this design was chosen to match the study's research aims, which aimed to explore the associations between artistic sports intervention and various psychological outcomes in a specific educational context, providing valuable insights into the potential benefits of PE for child development, particularly among LBCs.

2.2 Participants

Between September 2020 and January 2022, this study was conducted in six randomly selected primary schools in Hunan Province, Southern China. Southern China. Hunan Province, known for its diverse educational landscape and significant number of 'left behind' children due to urban migration, provides a unique context for studying the impact of physical education (PE) on child development. The China PE primary curriculum, which emphasizes the holistic development of students through physical activities, sports, and health education, plays a crucial role in the well-being of children, particularly those left behind by migrating parents. These schools were selected using a list provided by the government-sponsored Hunan Women and Children's Federation. Before the commencement of the study, the research team established a strong relationship with the school principals, obtaining their permission to proceed. Informational sessions were then conducted with teachers, parents, and guardians to clearly understand the research objectives, procedures, and potential benefits for the left-behind children. Informed consent forms were distributed to parents or guardians, emphasizing the voluntary nature of participation, and contact information was provided for any questions or concerns. Furthermore, interactive activities and workshops were organized in collaboration with the school staff to foster a supportive and inclusive environment, ensuring the active engagement and involvement of the left-behind children in the study.

Four hundred eighty-six (486) 9 to 13-year-old LBCs were invited to participate in the study. Each LBC voluntarily registered, and parent/guardian consent was required to participate. Before data collection, the research was approved by the ethics committee of Hunan Agricultural University (Approval Reference Number: ETHICS 2022107) and was funded by the Hunan Provincial Social Science Foundation in China (Project Reference Number: XSP21YBC310). During the sessions, 405 out of 486 participants completed the study; 50.4% (204) were Male, and 49.6% (201) were Female. All participants provided written informed consent, and the research was conducted according to the Helsinki Declaration. The questionnaires were administered using a paper-and-pencil format to ensure ease of completion and to maintain the tradition of personal engagement in our research methodology.

During pre-intervention (September 2020) and post-intervention (January 2022), trained research assistants administered self-reported questionnaires, including a sociodemographic questionnaire the Morgan-Jinks Student Efficacy Scale (Jinks and Morgan, 1999), Self-Esteem Scale (Rosenberg, 1965; Cheng and Hamid, 1995), and Asher's Loneliness and Social Dissatisfaction Questionnaire (Asher et al., 1984).

2.3 Tools "questionnaires"

2.3.1 Morgan-Jinks student efficacy scale

The Morgan-Jinks Student Efficacy Scale is a tool to determine children's academic self-efficacy. The scale comprises 30 items, and it uses a 4-point Likert scale that reflects informal language typically used by children. To assess the participating children's perceived academic self-efficacy at the baseline, we utilized the Chinese version of Jinks and Morgan (1999) Morgan-Jinks Student Efficacy Scale (Zhou et al., 2023). This scale assists practitioners in evaluating students' beliefs in their academic capabilities by featuring statements such as "I work hard in school" to gage students' self-efficacy beliefs toward academic success.

2.3.2 Rosenberg's self-esteem scale

Rosenberg's self-esteem scale measures an individual's self-worth and evaluates children's or adolescents' perceptions of their worth (Rosenberg, 1965; Cheng and Hamid, 1995). We used the Chinese version of Rosenberg's (1965) Self-Esteem Scale (RSES-C) to evaluate the self-esteem of the children who participated in the study (Wu et al., 2017). The questionnaire contains ten (10) items on the scale: five (5) items related to positive self-esteem and five (5) items related to self-deprecation, with items such as, "I take a positive attitude toward myself".

2.3.3 Asher's loneliness scale

According to Asher et al. (1984), the Children's Loneliness Scale measures children's perception of loneliness and social dissatisfaction. We have utilized Asher et al.'s (1984) Child Loneliness Scale (CLS-C) in its Chinese version. The CLS-C has been validated and previously used effectively in research focused on Chinese left-behind children's loneliness (Chen et al., 2014). The questionnaire consists of 24 items, 16 of which address children's feelings of loneliness, and the rest focuses on social adequacy (Cassidy and Asher, 1992), employing statements like, "No children play with me." Each item is rated on a 5-point Likert scale (1 = "totally disagree" to 5 = "totally agree").

2.4 Procedure and intervention

Two artistic sports activities, Aerobic Gymnastics and Latin American dance, were selected between September 2020 and January 2022. One hour and 30 min per lesson, two lessons per week over three semesters, 32 lessons each semester, 96 lessons and 144 h in total. (Three semesters: September 2020 to January 2021, February to June 2021, and September 2021 to January 2022).

Students in six schools (two classes per school) were instructed in the same sub-types of Latin American dance (Samba and Cha-Cha) and Aerobic Gymnastics. At one school, one class taught Latin American dance, and the other taught Aerobic Gymnastics to compare the effectiveness of both activities.

The course consists of three major components: basic dance movements, dance routines for solos and couples, and music understanding. All dance routines were taught to the LBCs during three semesters.

Before the intervention, thirty-six (36) qualified teachers (teachers' average years of expertise is 6.5, and at least had a minimum of three (3) years of children's teaching experience) were selected, eighteen (18) each for Aerobic Gymnastics and Latin American Dance. Within each dance style, a random drawing was conducted to divide eighteen (18) teachers into six (6) LBCs' primary schools. Finally, three (3) places for Aerobic Gymnastics and Latin American Dance teachers were set down in one (1) LBC's primary school. To avoid the potential influence of teacher effects on the variables' scores assigned to the children, all teachers involved in the study underwent a unified teaching content learning and training program at the same university before the research commenced. The training program aimed to standardize the instruction and delivery of Aerobic Gymnastics and Latin American dance among all teachers, providing them with detailed guidelines and instructional materials. By equipping the teachers with the necessary expertise to effectively teach these activities to the LBCs, the training program ensured consistent and standardized implementation of the intervention strategies.

Additionally, a team of six PhD-level researchers with backgrounds in psychology was also trained in advance to help collect data and assist the students as they filled out the questionnaire. They utilized non-directive assistance (encouraging LBCs to provide technical support, clarifications, or answer procedural questions if needed, but did not offer any opinions or suggestions that could sway the children's decisions). They assured them that their responses would remain anonymous and confidential. At the outset and conclusion of the intervention study in six schools, students were asked to complete sociodemographic and three standardized paper-and-pencil questionnaires regarding their academic self-efficacy, self-esteem, and loneliness.

2.5 Data analysis

This study examines artistic sports activities interventions (Aerobic Gymnastics and Latin American Dance) to improve students' academic self-efficacy and self-esteem, reduce loneliness among LBC students in rural areas, and enhance academic performance. Firstly, the Shapiro–Wilks test was chosen for its appropriateness in analyzing the normal distribution of variables within the sample size, considering the participants' gender and engagement in two distinct artistic sports activities. To ensure the reliability and validity of the questionnaires used in this study, both Cronbach's alpha (α) and the Kaiser-Meyer-Olkin (KMO) coefficient were calculated. Furthermore, the relationships among academic self-efficacy, loneliness, and self-esteem (including its sub-dimensions, Positive Esteem and Self-Deprecation) were initially explored using Pearson correlation analysis (R-values) to identify the strength and direction of these associations.

Then, independent samples t-tests were conducted to compare differences across various demographic variables, including gender. Additionally, paired samples t-tests were utilized to examine the differences in psychological indicators related to artistic sports activities before and after the intervention. Following this, Pearson correlation analysis was employed to determine the relationships among the variables (i.e., LCB's academic self-efficacy, self-esteem, and loneliness), laying the groundwork for testing mediator and moderator effects (Ren and Li, 2020). This clarification specifies the types of t-tests performed, enhancing the reader's understanding of the statistical methods used.

Meanwhile, mediation analyses were conducted using the pre-interventional data, which included the psychometric variables of "students' academic self-efficacy," "self-esteem," and "loneliness." These analyses aimed to explore whether loneliness served as a mediator between self-esteem and academic self-efficacy among left-behind children (LBCs), with the pre-intervention data chosen for its potential to reflect the actual mental state of LBCs better after the data collection had ended. The findings from these analyses will provide insights into the interplay between self-esteem, loneliness, and academic self-efficacy among LBCs, shedding light on the mechanisms that may influence their academic performance.

Multiple linear regression was employed to assess the role of loneliness as a mediator between self-esteem and student's academic self-efficacy, using bootstrapping to test the significance of the indirect effect. For this purpose, 95% bias-corrected confidence intervals were generated through Bootstrap sampling. An indirect effect was considered significant if the 95% bias-corrected confidence interval did not include zero. The statistical analyses were performed using SPSS 28.0, including the PROCESS macro by Hayes (2017) for bootstrapping procedures essential for testing the significance of indirect effects in mediation analysis, which ensuring a precise and reliable examination of the hypothesized relationships.

3 Results

3.1 Participant characteristics and reliability-validity of scales

During the sessions, 83.4% (405 out of 486) participants (9 to 13 years old) completed the study; 50.4% (204) were Male, and 49.6% (201) were Female. The 16.6% withdrew for various reasons, including lack of interest and shyness. The Shapiro–Wilk test results indicated the data were normally distributed (p values >0.05). Using Cronbach's alpha (α) and Kaiser-Meyer-Olkin (KMO) coefficients, the study showed good reliability and validity of the overall scales. Morgan and Jink's children's perceived academic self-efficacy scale are both 0.75 (Good) and 0.79 (Average suitability), Rosenberg's self-esteem scale, Cronbach's alpha coefficient is 0.83 (Good), while the KMO coefficient is 0.9 (Suitable), Asher children's loneliness scale, Cronbach's alpha coefficient in this study is 0.71 (Good), and the KMO coefficient is 0.78 (Average suitability).

3.2 Impact of artistic sports activities among left-behind children

Pre- and Post-student academic self-efficacy have a $p<0.01$ ($t=-39.22$, $p=0.000$), and the specific comparison difference shows that Pre-student academic self-efficacy (62.70 ± 10.48) has a significantly lower average value than Post-student academic self-efficacy (90.60 ± 9.41); while the specific comparison difference shows that Pre- Self-Esteem (15.42 ± 3.21) is significantly lower than Post-Self-Esteem (28.79 ± 4.91), with a level of $p<0.01$ significance between the two tests ($t=-45.38$, $p=0.000$); also A $p<0.01$ level of significance exists between Pre- and Post-Loneliness ($t=6.69$, $p=0.000$), the specific comparison difference indicates a significantly higher average value for Pre-Loneliness (35.12 ± 8.02) than Post-Loneliness (33.36 ± 7.72). All data are reported in Table 2, which evidence that artistic sports activities significantly impact all LBC's psychological variables of student academic self-efficacy, self-esteem, and loneliness.

In terms of different artistic sports activities there was also a significant positive impact on all LBC's psychological variables in different artistic sports activities (Aerobic Gymnastics and Latin American Dance) between pre-test and post-test ($p<0.01$). In the Aerobic Gymnastics intervention group, post-test scores for self-esteem and student academic self-efficacy were significantly higher than pre-student academic self-efficacy scores ($t=-28.77$, $p<0.01$) and pre-self-esteem ($t=-33.12$, $p<0.01$), also post-test loneliness scores were significantly lower than pre-test levels ($t=4.73$, $p<0.01$). In the Latin American Dance group intervention group, post-test scores for self-esteem and student academic self-efficacy were significantly higher than pre-student academic self-efficacy scores ($t=-26.72$, $p<0.01$) and pre-self-esteem ($t=-31.13$, $p<0.01$), also post-test loneliness scores were significantly lower than pre-test levels ($t=4.73$, $p<0.01$). Data are reported in Table 3.

3.3 Self-efficacy, self-esteem, and loneliness

Table 4 provides correlation and statistical information for the main variables between the five items, including self-esteem with its two sub-dimensions (positive esteem and self-deprecation), student academic self-efficacy, and loneliness. The R-value indicates the degree of correlation between each variable by identifying strong or weak correlations. The specific analysis shows that student academic self-efficacy is strongly positively correlated with self-esteem ($r=0.117$, $p<0.05$) and strongly negatively correlated with loneliness ($r=-0.276$), with a significant statistical correlation ($p<0.01$). A significant positive correlation was also found between student academic self-efficacy and the two self-esteem sub-dimensions "positive self-esteem ($r=0.105$, $p<0.05$)" and "self-deprecation ($r=0.109$, $p<0.05$)." Additionally, self-esteem exhibited a significant negative correlation with loneliness ($r=-0.168$, $p<0.01$), as well as loneliness demonstrated a significant negative correlation with two sub-dimensions of self-esteem, "positive self-esteem" ($r=-0.134$, $p<0.01$) and "self-deprecation" ($r=-0.176$, $p<0.01$).

TABLE 2 Pre-test and post-test of artistic sports activities group intervention ($N=405$).

Group	Paired statistics (Mean ± SD)		Paired mean	T	p-value
	Pre-test	Post-test			
Academic self-efficacy	62.70 ± 10.48	90.60 ± 9.41	−27.90	−39.220	0.000**
Male	63.44 ± 10.25	89.31 ± 9.75	−25.87	−25.897	0.000**
Female	61.95 ± 10.67	91.91 ± 8.88	−29.96	−30.118	0.000**
Self-Esteem	15.42 ± 3.21	28.79 ± 4.91	−13.37	−45.380	0.000**
Male	15.22 ± 3.01	28.46 ± 4.85	−13.24	−32.690	0.000**
Female	15.63 ± 3.40	29.13 ± 4.97	−13.50	−31.463	0.000**
loneliness scale	35.12 ± 8.02	33.36 ± 7.72	1.76	6.693	0.000**
Male	34.63 ± 8.27	33.46 ± 7.59	1.17	4.098	0.000**
Female	35.67 ± 7.71	33.25 ± 7.88	2.41	5.350	0.000**

Table shows the general means (Mean), standard deviations (SD). Paired T-tests to exam differences Pre-, Post- Test. **Indicates a significant relationship between the variables. *Significant ($p<0.05$) **Significant ($p<0.01$).

3.4 Mediator's role of loneliness

As shown in Table 5, study results indicated that in Model 1: self-esteem is an effective predictor of student academic self-efficacy ($\beta=0.117$, $p<0.05$). Consequently, in Model 2, the study employed loneliness as the dependent variable and self-esteem as the predictor variable. It was found that self-esteem had an effect on the prediction of Loneliness ($\beta=-0.168$, $p<0.01$). Furthermore, in Model 3, using student academic self-efficacy as the dependent variable and self-esteem and loneliness as the independent variables, the results of the multiple linear regression analysis revealed that when the loneliness variable was included, the regression coefficient of self-esteem for student academic self-efficacy decreased (Tables 5, 6) displays total effect ($c=0.223$) and direct effect ($c'=0.138$) and significant ($\beta=0.072$, $p<0.01$). As well the results show that loneliness can effectively predict student academic self-efficacy ($\beta=-0.264$, $p<0.01$).

Moreover, Table 6 shows that indirect of self-esteem on academic self-efficacy via decreased loneliness was significant for 95% Boot CI

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TABLE 3 Pre-test and post-test of aerobic gymnastics group/Latin American dance group intervention ($N = 405$).

Group		Paired statistics (Mean ± SD)		Paired mean	T	p-value
		Pre-test	Post-test			
Aerobic Gymnastics	Academic self-efficacy	62.34 ± 10.28	90.73 ± 9.53	−28.39	−28.77	0.000**
	Self-Esteem	15.26 ± 3.05	28.52 ± 4.79	−13.26	−33.12	0.000**
	Loneliness scale	34.77 ± 7.90	33.01 ± 7.55	1.76	4.73	0.000**
Latin American Dance	Academic self-efficacy	63.05 ± 10.68	90.47 ± 9.31	−27.41	−26.72	0.000**
	Self-Esteem	15.58 ± 3.37	29.06 ± 5.04	−13.48	−31.13	0.000**
	Loneliness scale	35.47 ± 8.13	33.71 ± 7.89	1.76	4.73	0.000**

Table shows the general means (Mean), and standard deviations (SD). Paired T-tests to exam differences Pre-, Post- Test. **indicates a significant relationship between the variables. *Significant ($p < 0.05$); **Significant ($p < 0.01$).

TABLE 4 Descriptive statistics and Pearson correlation coefficient table ($N = 405$).

	Mean	SD	1	2	3	4	5
Age	10.510	1.360					
1. Self-Esteem	28.790	4.914	1				
2. Positive Esteem	15.800	2.685	0.920**	1			
3. Self-Deprecation	12.990	2.662	0.918**	0.690**	1		
4. Academic Self-Efficacy	90.600	9.407	0.117*	0.105*	0.109*	1	
5. Loneliness	33.363	7.719	−0.168**	−0.134**	−0.176**	−0.276**	1

All tests were two-tailed. This table shows the general means (Mean), standard deviations (SD), and correlations of the six major variables. **Indicates a significant correlation between the variables, which obtains between all the variables. *Significant ($p < 0.05$); **Significant ($p < 0.01$).

TABLE 5 Direct effect of loneliness on self-esteem and academic self-efficacy ($N = 405$).

Independent variable	Dependent variable	β	T	R^2	Adjusted R^2	F
Self-esteem	Academic self-efficacy	0.117	2.358	0.014	0.011	5.562*
Self-esteem	Loneliness	−0.168	−3.429	0.028	0.026	11.755**
Self-esteem	Academic self-efficacy	0.072	1.489	0.081	0.077	17.817**
Loneliness		−0.264	−5.448			

Model 1, Regression model of "Academic self-efficacy" to "General Self-Efficacy" Model 2, Regression model of "Academic self-efficacy" to "Self-Esteem" Model 3, Regression model of "Academic self-efficacy" with the mediating variable "Self-Esteem" to "General Self-Efficacy". *Significant ($p < 0.05$). **Significant ($p < 0.01$).

TABLE 6 Indirect effect results.

Item	B(c) TE	a	b	a*b ME	B(c') DE	a*b (95% Boot CI)
Self-esteem => Loneliness => Academic self-efficacy	0.223*	−0.264**	−0.322**	0.085	0.138 **	0.012 ~ 0.088

"B(c)": Represents the regression coefficient of "Academic self-efficacy" to "General Self-Efficacy" (no mediator Self-Esteem in the model), i.e., Total Effect (TE). "B(c')": Represents the regression coefficient of "Academic self-efficacy" to "General Self-Efficacy" (included mediator Self-Esteem in the model), i.e., Direct Effect (DE). "a": Represents the regression coefficient of "Academic self-efficacy" to "Self-Esteem." "b": Represents the regression coefficient "Self-Esteem" to "General Self-Efficacy." "a*b": Represents the product of a and b, i.e., Mediation effect (ME). 95% Boot CI represents the 95% confidence interval calculated by Bootstrap sampling, if the interval does not include 0, it means significant. "Effect Ratio": If it is a complete mediation, the effect ratio is 100%; If it is a partial mediation, the formula is: a*b/c; If the mediation effect is not significant, the effect ratio is 0%. *Significant ($p < 0.05$). **Significant ($p < 0.01$).

(the interval is 0.012 ~ 0.088, does not include 0), and the mediation effect was 0.085, which demonstrates that loneliness mediates self-esteem and student academic self-efficacy. The findings above indicate that loneliness influences the relationship between academic self-efficacy and self-esteem among LBC students. Loneliness is perceived as a mediator.

To simplify the model, the mediating effect of loneliness in the multiple linear regression model is shown in Figure 1.

4 Discussion

4.1 Summary of findings

Among Chinese LBCs, the results supported the hypothesis that artistic sports activities (Aerobic Gymnastics and Latin American Dance) intervention can significantly boost academic performance by improving students' academic self-efficacy and self-esteem and

FIGURE 1
Model of mediation effect (indirect effects). **Significant ($p < 0.01$).

decreasing loneliness. Moreover, based on the preconditions of loneliness being strongly negatively correlated with LBC's self-esteem and academic self-efficacy, the findings also supported the hypothesis that loneliness was a mediator of the relationship between academic self-efficacy and self-esteem among LBCs.

4.2 Highlights and implications

4.2.1 Impact of artistic sports activities among left-behind children

The data reveals that the psychological variables of self-esteem and academic self-efficacy significantly improved after Aerobic Gymnastics and Latin American dance practice. The result is consistent with previous studies on Aerobic Gymnastics activities, which show that aerobic gymnastics cannot only have a positive effect on students' academic performance (Marino, 2010; Lucky, 2016) but also improve their self-esteem (Marino, 2010), after a study Marino (2010) in which 64 students (8–10 years old) participated in an aerobic dance intervention once a week for 8 weeks during their physical education classes for 40 min. However, research on Latin American dance's impact on academic self-efficacy is limited. Some studies indicate that dance participation may improve students' academic performance, such as Higueras-Fresnillo et al. (2016) study, 714 young girls aged 11.83 ± 2.50 who participated in dance scored significantly higher in academic performance (Mathematics and Language) than those who did not. This supports our finding that Latin American dance positively impacts LBCs' academic self-efficacy.

Additionally, a study by Sanchez (2020) found that Latin American dance (salsa) promotes compassion and healthy self-esteem in children, and Yuan (2021) concluded that Latin American dance not only has a positive effect on self-esteem and its dimensions but also can enhance learners' mental health through better social development. A systematic review by Park (2021) found that dance movement (dance-related activities) could improve children's self-esteem. Based on this study, research data indicate that Latin American dance interventions in LBCs can effectively improve their academic self-efficacy.

The results highlight that artistic sports activities can help LBCs become more socially connected and create peer relationships to reduce loneliness, improve a student's self-esteem and enhance academic self-efficacy, resulting in better academic performance. Studies on the impact of artistic sports activities (Aerobic Gymnastics and Latin American Dance) on loneliness are relatively scarce. Some studies indicate that participation in sports may reduce feelings of loneliness among children, as Page et al. (1992) found that children (ages 6 to 11) who participated in sports reported lower levels of loneliness, and Weiss and Smith (2002) found that participating in sports can reduce feelings of loneliness by providing positive peer interaction. This is probably why artistic sports activities positively impact the loneliness of LBCs.

4.2.2 Mediator's role of loneliness

This is the first research concerning whether loneliness mediates self-esteem and academic self-efficacy in LBCs. Based on the theoretical explanation in the introduction section revealed that individuals' mental states are influenced by a combination of self-influence factors and social systems (family and peers). Therefore, the relationships individuals have with their family and peers have the potential to impact self-influence factors, such as self-esteem and academic self-efficacy, in which loneliness is one of the impacted factors that family and peers influence.

Based on the findings, loneliness mediated the relationship between academic self-efficacy and self-esteem among LBCs. There are two reasons to support this result. Firstly, student academic performance is strongly negatively correlated with loneliness after studying 438 elementary school students from 9 to 13 in China (Lian-Yun, 2013), and loneliness scores were negatively correlated with academic self-efficacy after investigating school children's drinking behavior (mean age 13.5 years) (McKay et al., 2017). Secondly, loneliness among LBCs is closely related to the absence of parental support (Li et al., 2021) and friendship (Zhang et al., 2021).

4.3 Conclusion

The results show that Artistic Sports Activities (Aerobic Gymnastics and Latin American Dance) intervention can effectively and positively improve each psychometric test variable of students' academic self-efficacy, self-esteem, and loneliness among LBCs in Chinese rural areas to boost students' academic performance, which matched the research aim of this study. The results also show that loneliness mediated the relationship between academic self-efficacy and self-esteem among LBCs.

This study offers new insights into how artistic sports like Aerobic Gymnastics and Latin American Dance affect Left-Behind Children (LBCs) in three main areas: academic confidence (self-efficacy), self-esteem, and feelings of loneliness. Our work especially shows the psychological benefits of these artistic sports. We found that loneliness impacts LBCs' feelings about themselves and their academic abilities and is crucial in linking the two. This helps us understand better how emotions and social connections influence learning and self-view among LBCs. For educators and those working with children, our findings suggest a practical way to help LBCs feel better about themselves and do better in school. By including Aerobic Gymnastics and Latin American Dance in school activities, we can address their academic needs and improve their mental health and social connections. This approach could make a significant difference for LBCs, offering them a more supportive and enriching school experience.

4.4 Limitations and future research directions

Several limitations were noticed in this study. The study examined the effects of artistic sports activities (Aerobic Gymnastics and Latin

American Dance) on the academic performance of LBC, which considered the two styles as interventions. It would be more valuable to explain the impacts of different artistic sports activity styles, such as Figure Skating, ballroom dance, or Synchronized Swimming. (ii) Intervention was carried out only three semesters (one and a half years). Thus, a more comprehensive analysis of the long-term effects of our study is necessary. Meanwhile, this study did not include a control group, a limitation that merits acknowledgement. While employing a within-person/repeated measure intervention design allowed for the observation of significant differences in study outcome variables at pre- and post-intervention phases, the absence of a control group raises uncertainties regarding the extent to which observed changes can be attributed directly to the intervention, as opposed to other unobserved variables or changes occurring during the study period. Future iterations of this research will benefit from incorporating a control group to enhance the clarity and reliability of the results obtained.

For future research, these findings address a previous void in the literature, emphasizing the potential of artistic sports activities to reinforce psychological well-being among LBC groups. In the context of school psychology, this implies that interventions aimed at elevating self-esteem and mitigating feelings of loneliness can further bolster the academic self-efficacy of LBCs, thereby improving their academic performance. The increased social connectivity and peer relationship development stemming from these activities highlight their value in mitigating loneliness, thus boosting students' self-esteem and academic self-efficacy, resulting in better academic performance. Educators, school psychologists, researchers, and practitioners should consider integrating such artistic sports activities within the school curriculum, whether in PE or art classes, to harness these psychological benefits for LBCs. Future research might explore diverse artistic sports activity formats to curate sustainable interventions and also delve into a broader spectrum of psychological metrics, like social anxiety, to yield more holistic insights into the efficacy of these artistic sports activity interventions.

Data availability statement

Due to ethics restrictions, the data are not publicly available. The data can be obtained from the corresponding author based on a reasonable request for research purposes. Requests to access the datasets should be directed to Zhouyutao@hut.edu.cn.

Ethics statement

The studies involving humans were approved by Hunan Agricultural University (Approval Reference Number: ETHICS 2022107). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

YZ: Writing – original draft, Writing – review & editing. FF: Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – review & editing, Writing – original draft. CF: Conceptualization, Formal analysis, Funding acquisition, Methodology, Resources, Software, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1366501/full#supplementary-material

References

Affuso, G., Zannone, A., Esposito, C., Pannone, M., Miranda, M. C., De Angelis, G., et al. (2022). The effects of teacher support, parental monitoring, motivation and self-efficacy on academic performance over time. *Eur. J. Psychol. Educ.* 38, 1–23. doi: 10.1007/s10212-021-00594-6

Asher, S. R., Hymel, S., and Renshaw, P. D. (1984). Loneliness in children. *Child Dev.* 55, 1456–1464. doi: 10.2307/1130015

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychol. Rev.* 84, 191–215. doi: 10.1037/0033-295X.84.2.191

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Macmillan.

Bandura, A. (2012). *Handbook of theories of social psychology*, vol. *1*. Thousand Oaks, CA: SAGE Publications Ltd.

Bhatt, S., and Bahadur, A. (2018). Importance of self-esteem and self-efficacy for college students. *Indian J. Community Psychol.* 14, 409–419.

Bronfenbrenner, U. (1992). *Ecological systems theory*. London: Jessica Kingsley Publishers.

Cacioppo, S., Grippo, A. J., London, S., Goossens, L., and Cacioppo, J. T. (2015). Loneliness: clinical import and interventions. *Perspect. Psychol. Sci.* 10, 238–249. doi: 10.1177/1745691615570616

Cassidy, J., and Asher, S. R. (1992). Loneliness and peer relations in young children. *Child Dev.* 63, 350–365. doi: 10.2307/1131484

Cavanaugh, A. M., and Buehler, C. (2016). Adolescent loneliness and social anxiety: the role of multiple sources of support. *J. Soc. Pers. Relat.* 33, 149–170. doi: 10.1177/0265407514567837

Chen, Z., Hu, Z., and Zheng, Q. (2022). *Research on the mental health problems of left-behind children in rural China*. 2022 8th International Conference on Humanities and Social Science Research (ICHSSR 2022).

Chen, X., Wang, L., Li, D., and Liu, J. (2014). Loneliness in Chinese children across contexts. *Dev. Psychol.* 50, 2324–2333. doi: 10.1037/a0037689

Cheng, S.-T., and Hamid, P. N. (1995). An error in the use of translated scales: the Rosenberg self-esteem scale for Chinese. *Percept. Mot. Skills* 81, 431–434. doi: 10.1177/003151259508100214

Fife, J. E., Bond, S., and Byars-Winston, A. (2011). Correlates and predictors of academic self-efficacy among African American students. *Education* 132, 141–148,

Fuentealba-Urra, S., Rubio, A., Flores-Rivera, C., González-Carrasco, M., Oyanedel, J. C., Castillo-Quezada, H., et al. (2022). Physical activity habits and their relationship with sociodemographic factors in Chilean adolescents. *Front. Psychol.* 13:915314. doi: 10.3389/fpsyg.2022.915314

Gu, X. (2022). 'Save the children!': Governing left-behind children through family in China's great migration. *Curr. Sociol.* 70, 513–538. doi: 10.1177/0011392120985874

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York: Guilford Publications.

Hertler, S. C., Figueredo, A. J., Peñaherrera-Aguirre, M., Fernandes, H. B., Woodley of Menie, M. A., Hertler, S. C., et al. (2018). *Urie Bronfenbrenner: toward an evolutionary ecological systems theory*. Life history evolution: A biological Meta-theory for the social sciences, pp. 323–339.

Higueras-Fresnillo, S., Martínez-Gómez, D., Padilla-Moledo, C., Conde-Caveda, J., and Esteban-Cornejo, I. (2016). Dance participation and academic performance in youth girls. *Nutricion Hospitalaria* 33, 761–762. doi: 10.20960/nh.288

Honicke, T., and Broadbent, J. (2016). The influence of academic self-efficacy on academic performance: a systematic review. *Educ. Res. Rev.* 17, 63–84. doi: 10.1016/j.edurev.2015.11.002

Huang, C. (2011). Self-concept and academic achievement: a meta-analysis of longitudinal relations. *J. Sch. Psychol.* 49, 505–528. doi: 10.1016/j.jsp.2011.07.001

Hui, H. S., and Junyu, Y. (2014). Comparative study on the influence of modern dance and Latin dance on the physical fitness and physical self-esteem for male college students. *Sports Res. Educ.* 29, 115–118.

Jianshe Zhou, F. Q. (2020). Study on the stage division and performance form of the evolvement and development of the artistic sports in Chinese school. *J. Guangzhou Sport Univ.* 40, 120–123. doi: 10.13830/j.cnki.cn44-1129/g8.2020.02.028

Jinks, J., and Morgan, V. (1999). Children's perceived academic self-efficacy: an inventory scale. *Clearing House* 72, 224–230. doi: 10.1080/00098659909599398

Li, X., and Hu, H. (2021). The current situation and countermeasures of education and teaching of left behind children in rural areas. *Int. J. Electr. Eng. Educ.* 2021:7771. doi: 10.1177/00207209211007771

Li, M., Ren, Y., and Sun, H. (2020). Social anxiety status of left-behind children in rural areas of Hunan province and its relationship with loneliness. *Child Psychiatry Hum. Dev.* 51, 1016–1024. doi: 10.1007/s10578-020-01045-x

Li, Q., Zhang, W., and Zhao, J. (2021). The longitudinal associations among grandparent–grandchild cohesion, cultural beliefs about adversity, and depression in Chinese rural left-behind children. *J. Health Psychol.* 26, 140–155. doi: 10.1177/1359105318803708

Liang, L., Xiao, Q., and Yang, Y. (2018). The psychological capital of left-behind university students: a description and intervention study from China. *Front. Psychol.* 9:2438. doi: 10.3389/fpsyg.2018.02438

Lian-Yun, Z. (2013). An analysis of mediator variables between academic achievement and children'loneliness. *J. Psychol. Sci.* 36:922.

Liu, G., Teng, X., and Zhu, D. (2019). Effect of self-esteem and parents' psychological control on the relationship between teacher support and Chinese migrant Children's academic achievement: a moderated mediation. *Front. Psychol.* 10:2342. doi: 10.3389/fpsyg.2019.02342

Liu, W., Wang, W., Xia, L., Lin, S., and Wang, Y. (2022). Left-behind Children's subtypes of antisocial behavior: a qualitative study in China. *Behav. Sci.* 12:349. doi: 10.3390/bs12100349

Locke, E. A., and Latham, G. P. (2002). Building a practically useful theory of goal setting and task motivation: a 35-year odyssey. *Am. Psychol.* 57, 705–717. doi: 10.1037/0003-066X.57.9.705

Lucky, H. (2016). Aerobic gymnastic, fitness, anxiety, academic grade of health diploma students from remote area in Indonesia. *Int. J. Sci. Res.* 5, 1848–1852. doi: 10.21275/v5i7.art2016569

Mao, M., Zang, L., and Zhang, H. (2020). The effects of parental absence on children development: evidence from left-behind children in China. *Int. J. Environ. Res. Public Health* 17:6770. doi: 10.3390/ijerph17186770

Marino, D. M. (2010). *Effects of aerobic dance on self-esteem, academics, behavior, and social skills*. New York: Hofstra University.

Maslow, A., and Lewis, K. (1987). Maslow's hierarchy of needs. *Salenger Incorporated* 14, 987–990.

McKay, M. T., Konowalczyk, S., Andretta, J. R., and Cole, J. C. (2017). The direct and indirect effect of loneliness on the development of adolescent alcohol use in the United Kingdom. *Addict. Behav. Rep.* 6, 65–70. doi: 10.1016/j.abrep.2017.07.003

Morales-Rodríguez, F. M., and Pérez-Mármol, J. M. (2019). The role of anxiety, coping strategies, and emotional intelligence on general perceived self-efficacy in university students. *Front. Psychol.* 10:1689. doi: 10.3389/fpsyg.2019.01689

Mulyadi, S., Rahardjo, W., and Basuki, A. H. (2016). The role of parent-child relationship, self-esteem, academic self-efficacy to academic stress. *Procedia Soc. Behav. Sci.* 217, 603–608. doi: 10.1016/j.sbspro.2016.02.063

Neroni, J., Meijs, C., Kirschner, P. A., Xu, K. M., and De Groot, R. H. (2022). Academic self-efficacy, self-esteem, and grit in higher online education: consistency of interests predicts academic success. *Soc. Psychol. Educ.* 25, 951–975. doi: 10.1007/s11218-022-09696-5

Noronha, L., Monteiro, M., and Pinto, N. (2018). A study on the self-esteem and academic performance among the students. *Int. J. Health Sci. Pharm.* 2. doi: 10.47992/ijhsp.2581.6411.0021

Page, R. M., Frey, J., Talbert, R., and Falk, C. (1992). Children's feelings of loneliness and social dissatisfaction: relationship to measures of physical fitness and activity. *J. Teach. Phys. Educ.* 11, 211–219. doi: 10.1123/jtpe.11.3.211

Park, K. (2021). *Connecting the dots: Positive effect of dance movement therapy with immigrant children; a literature review*. Lesley University.

Perlman, D., and Peplau, L. A. (1982). Theoretical approaches to loneliness. Loneliness: a sourcebook of current theory. *Res. Ther.* 36, 123–134.

Qi, F. (2018). Artistic sports reinterpreted. *J. Xiamen Univ. Technol.* 2, 84–89. doi: 10.19697/j.cnki.11673-14432.201802014

Qualter, P., Vanhalst, J., Harris, R., Van Roekel, E., Lodder, G., Bangee, M., et al. (2015). Loneliness across the life span. *Perspect. Psychol. Sci.* 10, 250–264. doi: 10.1177/1745691615568999

Ren, Y., and Li, M. (2020). Influence of physical exercise on social anxiety of left-behind children in rural areas in China: the mediator and moderator role of perceived social support. *J. Affect. Disord.* 266, 223–229. doi: 10.1016/j.jad.2020.01.152

Rosenberg, M. (1965). *Rosenberg self-esteem scale (RSE)*. Acceptance Commitment Therapy. Measures package, No. 61. p. 18.

Saha, A. K. T. M. N. (2018). Effect of maternal depression on adolescents self-esteem and academic achievement. *J. Psychosoc. Res* 13, 275–285. doi: 10.32381/JPR.2018.13.02.2

Sanchez, D. (2020). *Dignity and respect in the salsa dance classroom: Fostering healthy self-esteem to promote compassion*.

Shan, H., and Yu, L. I. U. (2011). The experimental research of Latin's influence on the mental health of the higher-grade primary students. *Hebei Inst. Phys. Educatin* 25, 83–86.

Shen, J., Liu, X., Zhao, J., and Shi, B. (2015). The psychological development of Chinese left-behind children and migrant children in urbanization process. *Psychol. Dev. Educ.* 31, 108–116.

Wang, H., He, X., Tang, Y., Tang, J., and Yang, J. (2024). Unveiling the links between physical activity, self-identity, social anxiety, and emotional eating among overweight and obese young adults. *Front. Psychol.* 14:1255548. doi: 10.3389/fpsyg.2023.1255548

Wang, Y., Liu, W., Wang, W., Lin, S., Lin, D., and Wang, H. (2021). Left-behind children's social adjustment and relationship with parental coping with children's negative emotions during the COVID-19 pandemic in China. *Int. J. Psychol.* 56, 512–521. doi: 10.1002/ijop.12754

Wang, Q., Zhang, Y., and Liu, X. (2021). Perceived discrimination, loneliness, and non-suicidal self-injury in Chinese migrant children: the moderating roles of parent-child cohesion and gender. *J. Soc. Pers. Relat.* 38, 825–847. doi: 10.1177/0265407520974754

Wei, C., and Huang, Z. (2019). *Relationship among school atmosphere, self-esteem and loneliness of left-behind children*. 2018 international workshop on education reform and social sciences (ERSS 2018)

Weiss, M. R., and Smith, A. L. (2002). Friendship quality in youth sport: relationship to age, gender, and motivation variables. *J. Sport Exerc. Psychol.* 24, 420–437. doi: 10.1123/jsep.24.4.420

Wu, Y., Zuo, B., Wen, F., and Yan, L. (2017). Rosenberg self-esteem scale: method effects, factorial structure and scale invariance across migrant child and urban child populations in China. *J. Pers. Assess.* 99, 83–93. doi: 10.1080/00223891.2016.1217420

Yu, B.-L., Li, J., Liu, W., Huang, S.-H., and Cao, X.-J. (2022). The effect of left-behind experience and self-esteem on aggressive behavior in young adults in China: a cross-sectional study. *J. Interpers. Violence* 37, 1049–1075. doi: 10.1177/0886260520922373

10.3389/fpsyg.2024.1366501

Yuan, Y. (2021). Research on the influence of dance sport on the body-esteem of Chinese college students. *Sci. Soc. Res.* 3, 1–6. doi: 10.36922/ssr.v3i4.1220

Zhang, Z. (2009). On the causes for the generation of" artistic sports" and their common characteristics–the fusion of science and artistic body movement manners. *J. Phys. Educ.* 3, 11–14.

Zhang, H., Ma, A., and Li, Y. (2022). The role of social cohesion in preventing child abuse among rural Chinese left-behind children. *J. Interpers. Violence* 37:NP4510-NP 4526. doi: 10.1177/0886260520958657

Zhang, R., Qiu, Z., Li, Y., Liu, L., and Zhi, S. (2021). Teacher support, peer support, and externalizing problems among left-behind children in rural China: sequential mediation by self-esteem and self-control. *Child Youth Serv. Rev.* 121:105824. doi: 10.1016/j.childyouth.2020.105824

Zhou, Y.-M., Mak, L., Zhao, C.-X., He, F., Huang, X.-N., Tian, X.-B., et al. (2022). Correlates of suicidal ideation in rural Chinese junior high school left-behind children: a socioecological resilience framework. *Front. Psych.* 13:627. doi: 10.3389/fpsyt.2022.901627

Zhou, Z., Zhou, Y., Ferraro, F. V., Hooton, A., and Ribchester, C. (2023). The effects of Latino dance intervention on academic and general self-efficacy with left-behind children: an experimental study in China. *Front. Psychol.* 14:7233. doi: 10.3389/fpsyg.2023.1107233

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Motor competence and compliance with physical activity recommendations in Chilean schoolchildren

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The development of motor competence is thought to be a crucial precursor to raising the trajectory of PA throughout a person's life. The objectives of this study are to determine motor competence and the daily time of moderate and vigorous physical activity of students in 5th and 6th grade elementary in Chile, and to establish whether there are differences in motor competence according to sex and compliance with physical activity recommendations. 368 schoolchildren ($M = 11.10$ years; 54.3% girls) participated. To assess motor competence, the MOBAK 5–6 test was used. Physical activity was measured using ActiGraph wGT3X-BT® accelerometers. Boys ($M = 3.65$, SD = 2.14) showed better performance than girls ($M = 2.39$, SD = 1.80) in Object Control ($p \leq 0.001$, PS = 0.67). For Self-Movement, the girls ($M = 2.72$, SD = 2.14) performed better than the boys ($M = 2.40$, SD = 1.86); however, there were no significant differences between the two sexes ($p = 0.257$). Boys ($M = 48.4$, SD = 22.8) presented more daily minutes of moderate and vigorous physical activity than girls ($M = 35.9$, SD = 16.9), with statistically significant differences ($p \leq 0.001$, PS = 0.67). About MC according to compliance with the physical activity recommendations, only in Object Control there is a statistically significant difference ($p \leq 0.001$; PS = 0.29) between the students who comply with the recommendations ($M = 4.28$, SD = 2.12) and those who do not achieve the recommended minutes ($M = 2.67$, SD = 1.29). By contrast, an analysis of Self-Movement found no significant difference (complies: $M = 2.73$, SD = 1.97; does not comply: $M = 2.54$, SD = 2.04; $p = 0.408$) between the two groups. It is necessary to generate instances that develop motor competence in all its dimensions to promote higher levels of moderate to vigorous physical activity.

KEYWORDS

motor development, motor skills, motor competence, physical activity, physical literacy

1 Introduction

Physical activity (PA) provides multiple benefits to people's health (Telama et al., 2005); however, the number of people who comply with PA recommendations is very low (Hallal et al., 2012), including a large proportion of the child population (Aubert et al., 2022). Current worldwide PA recommendations for children and adolescents indicate that they should engage in an average of at least 60 min of mainly aerobic physical activity of moderate to vigorous intensity daily (World Health Organization, 2020), however, several studies indicate that low percentages of children and adolescents comply with these recommendations (Aubert et al., 2022). In the particular case of Chile, this situation is worse, as it is one of the countries with the worst PA-related indicators (Aubert et al., 2022). Through the use of accelerometers, several studies have objectively identified that the percentage of children and adolescents who comply with these recommendations ranges between 3.7 and 14.6% (Toledo-Vargas et al., 2020; Ceppi-Larraín et al., 2021). These figures show that sedentary behaviors can become entrenched among a high proportion of the Chilean child population if measures are not taken to address this issue (Aguilar-Farías et al., 2017). To reverse this problem, factors that favor the practice of regular PA need to be developed (Robinson et al., 2015), especially moderate and vigorous physical activity (MVPA) (Silva-Santos et al., 2021). One of these is motor competence (MC), which is thought to be a crucial precursor to raising the trajectory of PA throughout a person's life (Stodden et al., 2008; Barnett et al., 2016; Tyler et al., 2020).

MC is defined as a person's ability to dominate a variety of locomotor and stability skills, and control objects needed to carry out daily tasks (Utesch and Bardid, 2019). Theoretical models have suggested that MC interacts positively with PA (Stodden et al., 2008; Robinson et al., 2015), identifying MC as essential to a physically active lifestyle. Several empirical studies have confirmed this interaction based on these theoretical models, identifying a positive association between MC and PA (Holfelder and Schott, 2014; Logan et al., 2015; Lopes et al., 2020). In fact, PA and MC presented a reciprocal association across childhood and early adolescence (Lima et al., 2017).

Although the importance of developing MC in the child population is recognized, performance levels are concerning. In Europe, various studies have demonstrated that students have low MC, with a high proportion of students who require motor reinforcement (Herrmann et al., 2016; Quitério et al., 2017; Scheuer et al., 2019; Duncan et al., 2020; Wälti et al., 2022). In Latin America, particularly in Chile, the panorama is no different, and studies show low levels of MC (Martinez-Lopez et al., 2021; Rodríguez-Briceño et al., 2021; Müller et al., 2022; Quintriqueo-Torres et al., 2022; Carcamo-Oyarzun et al., 2023). Previous studies have already identified that most schoolchildren have gross motor development levels categorized as poor and very poor (Luarte et al., 2014; Bermúdez-Ferrales et al., 2015), which is why this situation has not changed in recent years. One important aspect to consider in MC development is the role of sex. There is strong evidence that boys present significantly higher levels in object control tasks, both in international (Iivonen and Sääkslahti, 2014; Barnett et al., 2016) and Chilean studies (Carcamo-Oyarzun and Herrmann, 2020; Martinez-Lopez et al., 2021; Rodríguez-Briceño et al., 2021). However, in tasks related to self-movement, there is no certain consensus, as in some studies the results indicate that girls perform better than boys (Iivonen and Sääkslahti, 2014), while in others no differences have been found between both sexes (Barnett et al., 2016). In studies within the Chilean context, the trend indicates that in the performance of boys and girls in self-movement skills there are no significant differences (Rodríguez-Briceño et al., 2021; Quintriqueo-Torres et al., 2022; Gonzalez-Huenulef et al., 2023).

Although previous studies have demonstrated the link between MC and PA (Lopes et al., 2020), further study is still needed to better understand this interaction (Barnett et al., 2022). Few studies have addressed this topic from the point of view of compliance with child physical activity recommendations; hence, this study has two purposes: (a) to determine motor competence and the daily time of moderate and vigorous physical activity of students in 5th and 6th grade elementary in Chile, and (b) to establish whether there are differences in motor competence according to sex and compliance with physical activity recommendations.

2 Method

2.1 Participants

A non-probability sample by convenience comprised 368 elementary students from 5th and 6th grade (M = 11.10, DE = 0.91 years; 54.3% girls) from five schools in la región de la Araucanía, Chile. The inclusion criteria were regular participation in physical education classes and having no health problems that would prevent them from performing the tests. All the participants had signed permission from their fathers, mothers, or guardians. In addition, each participant indicated their intention to participate by signing a consent form. The Universidad de La Frontera Scientific Ethics Committee approved the study protocol, file 125_17.

2.2 Instruments

2.2.1 Evaluation of motor competence

To assess MC, the MOBAK 5–6 test was used, which was created by Herrmann and Seelig (2017) and validated in Spanish by Carcamo-Oyarzun and Herrmann (2020). This test focuses on the resolution of 8 motor skills tasks consistent with the curricular objectives of the subject of physical education (Carcamo-Oyarzun et al., 2022). The structure of the test groups these tasks in 2 dimensions: (a) Object Control, corresponding to four tasks associated with motor manipulative skills (bouncing, dribbling, throwing, and catching), and (b) Self-Movement, comprised of four tasks linked to locomotor and stability skills (jumping, running, rolling, and balancing). Table 1 describes each of the tasks on the MOBAK 5–6.

There are 2 attempts for each motor task, except throwing and catching, where 6 attempts are included for each. The score is dichotomous (0 = unsuccessful, 1 = achieved). Therefore, a record of valid attempts must be kept considering that 0 times achieved is 0 points, 1 time achieved is 1 point, and 2 times achieved is 2 points. In the case of throwing and catching, considering there are 6 attempts, the score corresponds to 0 points when 0 to 2 times are achieved, 1 point for 3 to 4 times, and 2 points for 5 to 6 successful attempts. Then, the sum of the scores obtained in each task gives the score of the

TABLE 1 Descriptive summary of the tasks on the MOBAK 5–6 Test [adapted from Carcamo-Oyarzun and Herrmann (2020)].

Dimension	Task	Description
Object control	Throwing	Throw a ball to try to hit a circle marked on a wall from 3.5 m away.
	Catching	Throw a tennis ball against a wall and then catch it in the air.
	Bouncing	Bounce a size 6 basketball along a track (8.0 m x 1.1 m) with 4 obstacles.
	Dribbling	Dribble a size 4 indoor football along a track (8.0 m x 1.1 m) with 4 obstacles.
Self-movement	Balancing	Walk forwards and then back on a balanced upside-down bench with 2 obstacles 12 cm high.
	Rolling	Perform a forward somersault, starting off standing up and passing over a cardboard box.
	Jumping	Jump rope for 20 s., changing pace or form at 10 s.
	Running	Running forwards and diagonally in a square (4.0 m x 4.0 m), taking 3 steps over gymnastics hoops when running forwards.

respective dimension, with a possible score of a minimum of 0 points and a maximum of 8 points. The application details and scoring of the MOBAK 5–6 test can be found at https://www.mobak.cl/mobak-5-6.

2.2.2 Daily time of moderate and vigorous physical activity

To measure the amount of MVPA, the ActiGraph wGT3X-BT accelerometer was used, a device that records continuous and high-resolution data of physical activity for 24 h a day. The data were downloaded with a storage time of 60 s using the ActiLife 6.13.4 software. First, sleep was detected with the options Scoring Sleep and Detection Sleep to conduct an individual review to identify possible inconsistencies. Subsequently, the time of use was validated with the Choi algorithm, and it was stipulated that for the use of the accelerometer to be valid, it had to be used 4 days, where at least 1 must be a weekend and with a minimum of 10 h of correct use per day. Finally, the intensity of the physical activity was determined with the Evenson et al. (2008) algorithm. For a student to be included in the category of compliance with the physical activity recommendations, the physical activity recommendations proposed by the World Health Organization for children and adolescents between 5 and 17 years of age were taken as the baseline, consisting of 60 min of moderate to vigorous intensity physical activity per day (World Health Organization, 2020).

2.3 Procedure

The participants were asked to wear the accelerometer constantly for 7 days straight (Tudor-Locke et al., 2015). The accelerometers were programmed with a storage time of 60 s (epochs), 4 days of minimum use with at least 1 day on a weekend, considering 10 h of use adequate for a day to be valid, stipulating its use on the right side of the waist. Then, an accelerometer was delivered to each student at school with its respective code. The correct way to use it was explained, indicating that they must keep the device on for 7 days, including sleeping, and they can only take it off for showering, swimming, or any activity that would get the strap wet. Once they had their accelerometer, the students moved to the gymnasium to take the MOBAK 5–6 test, where trained evaluators had prepared each of the 8 motor tasks. Each evaluator was in charge of 3 to 5 students depending on the number of students in each course. Each motor task was first explained and then demonstrated. An approximate time between 45 and 60 min was considered to finish evaluating the entire group.

2.4 Statistical analysis

The data analysis was performed using SPSS Statistics 25.0. Descriptive analyses of central tendency were done. To determine the normality of the sample, the Kolmogorov–Smirnov test was used. After identifying that the sample presents a non-normal distribution, the Mann–Whitney U test was used to analyze the differences in motor competence based on sex and compliance with the physical activity recommendations. $p < 0.05$ was considered the level of significance. The probability of superiority (PS) was calculated to determine the effect size, an analysis recommended when using non-parametric tests that seek comparisons of two groups (Li, 2016). The interpretation corresponded to PS ≥ 0.56 as a small effect size, PS ≥ 0.64 as medium, and PS ≥ 0.71 as large (Grissom, 1994). To analyze whether there are sex differences between students who comply with the recommendations and those who do not, a nonparametric Kruskal-Wallis test was used.

3 Results

Table 2 provides the descriptive analyses of the motor tasks of the MOBAK 5–6 test and minutes of MVPA per day according to the student's sex. In terms of MC, for Object Control, the boys ($M = 3.65$, SD = 2.14) performed better than the girls ($M = 2.39$, SD = 1.80), being statistically different ($p \leq 0.001$, PS = 0.67). For Self-Movement, girls ($M = 2.72$, SD = 2.14) and boys ($M = 2.40$, SD = 1.86) exhibited similar values ($p = 0.257$). In terms of daily time of MVPA, the boys ($M = 48.4$, SD = 22.8) recorded more minutes than the girls ($M = 35.9$, SD = 16.9), with statistically significant differences ($p \leq 0.001$, PS = 0.67). Both groups' mean MVPA daily times are below the recommended 60 min daily that the World Health Organization suggests.

Figure 1 illustrates the percentages of compliance with the WHO's physical activity guidelines. 29.8% of the boys complied with the

TABLE 2 Descriptive statistics of motor tasks on the MOBAK 5–6 test and minutes of MVPA per day, based on sex.

	Girls (n = 200)			Boys (n = 168)			U	p	PS
	Mean (SD)	95% CI	Median	Mean (SD)	95% CI	Median			
Motor competence									
Throwing[i]	0.42 (0.59)	[0.34–0.50]	0.0	0.61 (0.68)	[0.50–0.72]	0.5	19267.0	0.006*	0.57
Catching[i]	0.34 (0.65)	[0.25–0.43]	0.0	0.77 (0.83)	[0.64–0.89]	1.0	21586.5	0.000*	0.64
Bouncing[i]	1.12 (0.84)	[1.00–1.24]	1.0	1.36 (0.78)	[1.24–1.48]	2.0	19426.0	0.005*	0.58
Dribbling[i]	0.51 (0.74)	[0.40–0.61]	0.0	0.90 (0.84)	[0.78–1.03]	1.0	21198.0	0.000*	0.63
Total object control[ii]	2.39 (1.80)	[2.13–2.64]	2.0	3.65 (2.14)	[3.32–3.97]	4.0	22500.5	0.000*	0.67
Balancing[i]	0.81 (0.81)	[0.69–0.92]	1.0	0.71 (0.81)	[0.58–0.83]	0.0	15660.0	0.225	-
Rolling[i]	0.58 (0.83)	[0.46–0.69]	0.0	0.58 (0.85)	[0.45–0.71]	0.0	16780.0	0.981	-
Jumping[i]	0.52 (0.77)	[0.41–0.62]	0.0	0.22 (0.52)	[0.14–0.30]	0.0	27883.0	0.000*	0.83
Running[i]	0.83 (0.84)	[0.71–0.94]	1.0	0.89 (0.84)	[0.76–1.02]	1.0	17479.0	0.474	-
Total self-movement[ii]	2.72 (2.14)	[2.42–3.02]	2.0	2.40 (1.86)	[2.11–2.68]	2.0	15662.6	0.257	-
Moderate to vigorous physical activity per day									
MVPA[iii]	35.9 (16.9)	[33.56–38.27]	32.5	48.4 (22.8)	[44.93–51.90]	46.0	22489.0	0.000*	0.67

[i]Range of 0 to 2 pts. [ii]Range of 0 to 8 pts. [iii]Minutes daily.

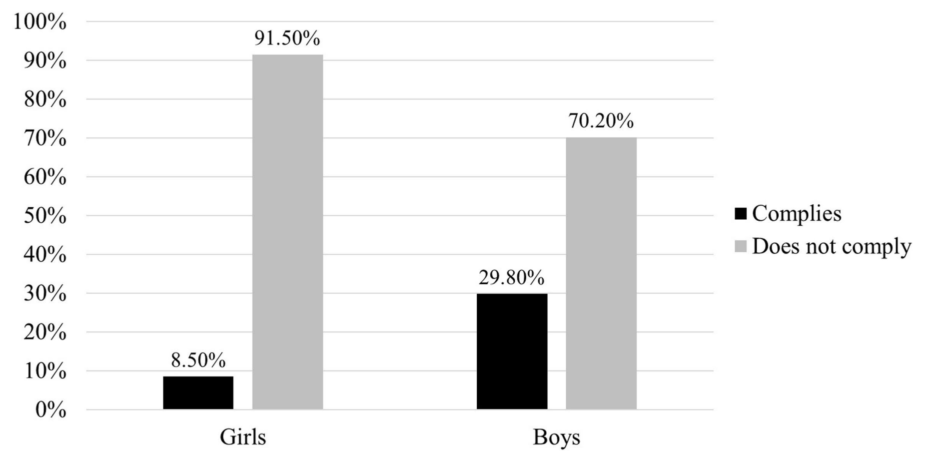

FIGURE 1
Compliance with the physical activity recommendations according to sex.

60 min of daily MVPA, a much higher percentage than the girls, as in this group, only 8.5% managed to achieve the recommended PA levels.

Table 3 describes the results in MC according to compliance with PA recommendations. In Object Control, there is a significant difference ($p \leq 0.001$; PS = 0.29) between the students who comply with the recommendations (M = 4.28, SD = 2.12) and those who do not achieve the recommended minutes (M = 2.67, SD = 1.29). By contrast, an analysis of Self-Movement found no significant difference (complies: M = 2.73, SD = 1.97; does not comply: M = 2.54, SD = 2.04; p = 0.408) between the two groups.

TABLE 3 Differences in motor tasks on the MOBAK 5–6 test based on compliance with physical activity recommendations.

	Complies (n = 67)			Does not comply (n = 301)			U	p	PS
	Mean (SD)	95% CI	Median	Mean (SD)	95% CI	Median			
Throwing[i]	0.73 (0.73)	[0.55–0.91]	1.0	0.46 (0.61)	[0.39–0.53]	0.0	8066.5	0.004*	0.40
Catching[i]	1.03 (0.89)	[0.81–1.25]	1.0	0.43 (0.69)	[0.35–0.50]	0.0	6356.5	0.000*	0.32
Bouncing[i]	1.48 (0.75)	[1.30–1.66]	2.0	1.18 (0.83)	[1.08–1.27]	1.0	8074.0	0.006*	0.40
Dribbling[i]	1.04 (0.86)	[0.83–1.25]	1.0	0.61 (0.78)	[0.52–0.70]	0.0	7286.5	0.000*	0.36
Total object control[ii]	4.28 (2.12)	[3.77–4.80]	5.0	2.67 (1.92)	[2.45–2.89]	2.0	5799.0	0.000*	0.29
Balancing[i]	0.72 (0.77)	[0.53–0.91]	1.0	0.77 (0.82)	[0.68–0.86]	1.0	10367.5	0.696	-
Rolling[i]	0.79 (0.90)	[0.57–1.01]	0.0	0.53 (0.82)	[0.44–0.62]	0.0	8506.5	0.018*	0.42
Jumping[i]	0.30 (0.60)	[0.15–0.45]	0.0	0.40 (0.70)	[0.32–0.48]	0.0	10676.5	0.331	-
Running[i]	0.93 (0.84)	[0.72–1.13]	1.0	0.84 (0.84)	[0.74–0.93]	1.0	9494.0	0.423	-
Total self-movement[ii]	2.73 (1.97)	[2.25–3.21]	2.0	2.54 (2.04)	[2.31–2.77]	2.0	9440.0	0.408	-

[i]Range of 0 to 2 pts. [ii]Range of 0 to 8 pts.

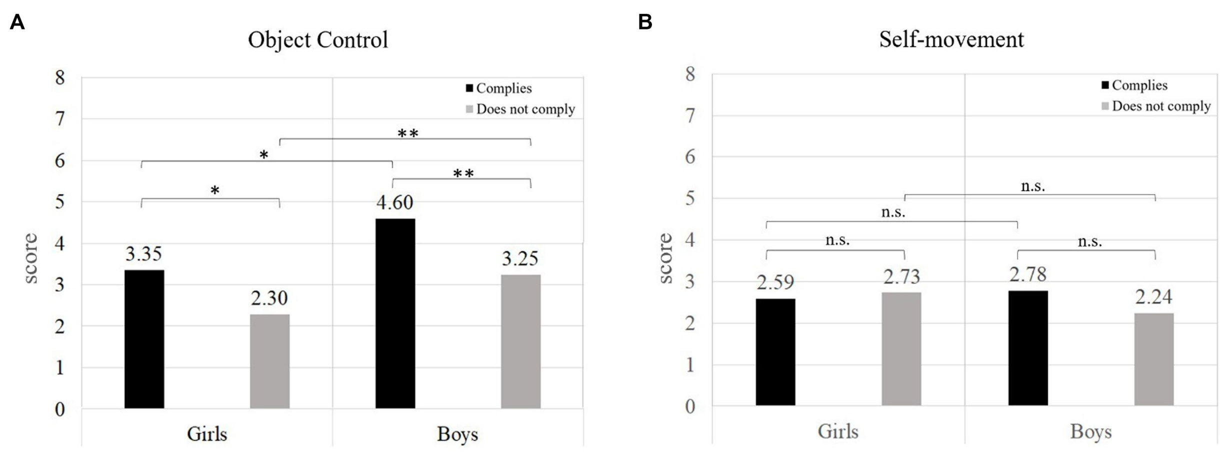

FIGURE 2
Comparison of motor competence according to sex between students who comply with the recommendations and those who do not. **(A)** Object control; **(B)** Self-movement. *significant differences at the level of $p \leq 0.05$; **significant differences at the level of $p \leq 0.001$; n.s., means no significant differences.

When analyzing whether there are differences according to sex between students who comply with the recommendations and those who do not, the results indicate that in Object Control there are significant differences ($H = 48.925$, df = 3, $p < 0.001$), specifically between boys and girls who comply ($p = 0.036$, PS = 0.67), boys and girls who do not comply ($p < 0.001$, PS = 0.64), girls who comply and girls who do not comply ($p = 0.024$, PS = 0.34), and boys who comply and boys who do not comply ($p < 0.001$, PS = 0.32) (Figure 2). Regarding the results of Self-Movement, no significant differences were found between the groups ($H = 3.712$, df = 3, $p = 0.294$).

4 Discussion

This study sought to analyze the MC and daily time of MVPA of 5th and 6th-grade elementary students in Chile and to establish if there are differences in MC based on sex and compliance with PA recommendations. The results referring to MC according to sex indicate that, in Object Control, there is a significant difference between the two groups, where the boys perform better than the girls, confirming this trend posited in international studies (Iivonen and Sääkslahti, 2014; Barnett et al., 2016; Brian et al., 2019) within the Chilean context (Carcamo-Oyarzun and Herrmann, 2020; Martinez-Lopez et al., 2021; Rodríguez-Briceño et al., 2021). In reference to the tasks associated with Self-Movement, girls obtained similar values than boys which is consistent with the findings of the systematic review by Barnett et al. (2016), where no differences or associations were determined according to sex in locomotor or stability tasks. Studies with a Chilean school population also agree with this tendency (Rodríguez-Briceño et al., 2021; Quintriqueo-Torres et al., 2022; Gonzalez-Huenulef et al., 2023). These differences could be explained by the existing stereotyping of physical activities, where the boys tend to participate in ball sports, whereas the girls participate in activities associated with body control (Crane et al., 2015; Temple et al., 2016).

With respect to the amount of MVPA that they do on average per day, the students analyzed reached a mean of 41.6 min of MVPA, below the times found in studies with Spanish students, who reached means between 53 and 56 min per day (Martínez Martínez et al., 2012; Calahorro-Cañada et al., 2015). In addition, the values of the Chilean students are below students in Australia (65 min per day) or Canada (58 min per day), although approaching students in India (48 min per day) and Brazil (44 min per day) (Thivel et al., 2019). When analyzing possible differences concerning sex, it is observed that boys perform more MVPA than girls, which coincides with other studies where boys are also found to be more active than girls (Glinkowska and Glinkowski, 2018; Gutierrez-Hervas et al., 2020; Ceppi-Larraín et al., 2021). This situation could be due to multiple factors, both biological, such as the structure of the muscle cells induced by sex hormones (Wang et al., 2019), and cultural, where boys receive more support and opportunities than girls for participating in certain physical activities (Temple et al., 2016).

Regarding the proportion of schoolchildren who meet the PA recommendations proposed by the WHO (60 min daily with moderate to vigorous intensity), in the sample studied, 18.2% reach this figure, which is higher than previous studies on the Chilean population, where it was identified that only 10.5% comply with this recommendation (Aguilar-Farias et al., 2021). Even so, these proportions show that most children in Chile do not comply with the current directives on PA, making it necessary to produce strategies that promote the factors associated with regular participation in physical activities (Guthold et al., 2020). Considering that MC is recognized as a factor that interacts bidirectionally with participation in PA (Barnett et al., 2022) when analyzing the MC results in terms of compliance with PA recommendations, it is noted that in Object Control, the children who comply with the PA recommendations show better results than the rest, with a significant difference. This situation is confirmed in comparisons by sex, where girls and boys who comply with PA recommendations differ significantly from their respective peers who do not comply. The results in Object Control agree with this MC-PA bidirectionality (Barnett et al., 2022); however, with respect to Self-Movement, although the students who comply with the PA recommendations have slightly higher values than those who do not, these differences are not statistically significant.

When the interaction between sex and PA recommendations was analyzed, interesting findings were obtained in object control skills. Boys and girls who comply with PA recommendations outperformed their peers who do not comply. These results underscore the need to offer programs to increase regular participation in PA, which includes activities that enable the development of the two dimensions of MC. Several studies have identified that the students who participate in physical-sport workshops outside school do more PA and present better indicators in their MC (Strotmeyer et al., 2020; Müller et al., 2022; Wälti et al., 2022; Carcamo-Oyarzun et al., 2023). Thus, the results of this study serve as input for teachers on which to base their methodological strategies oriented to the development of MC. At the same time, schools can promote activities that offer opportunities for their students to have various options for PA, like extracurricular workshops focusing on developing MC. Moreover, we cannot leave out the promotion of public policies where the aforementioned measures are reinforced to strengthen the development of schoolchildren and generate active and healthy lifestyles over time. These results are important not only because they add to the limited evidence that exists in Latin America on this issue, but also because they highlight the need to take measures to promote physical activity and the development of physical literacy in this region (Ortega-Benavent et al., 2024).

Despite the relevant findings presented, this study is not without limitations. It is possible to mention that the study design, being cross-sectional, does not determine causal links between MC and PA. Another limitation is that it must be borne in mind that the number of schoolchildren who comply with PA recommendations is very low, which is why the differences encountered must be considered with caution. Furthermore, this study did not consider the type of PA that students develop or its context, which could have given more robust information concerning the results of MC based on compliance with PA recommendations. However, it is also important to highlight the strengths of the study, which lie in the instruments used for data collection. The measurement of MVPA time using accelerometers stands out, providing much more objective data than other assessment tools, such as self-reported questionnaires. On the other hand, it is also important to point out that the evaluation of MC has been performed previously with a test validated for the school population participating in this study. For future studies, we recommend considering other intensities in addition to MVPA, and even considering compositional and isotemporal analyses, to see if increasing a certain number of minutes of MVPA at the expense of sedentary or light PA can help to achieve the minimum recommendations. In addition, we recommend to use longitudinal designs to understand the bidirectionality in the interaction between MC and PA, as well as the inclusion of underlying variables that act as mediators in this association, such as perceived MC and health-related physical conditioning.

In conclusion, in this study, differences were found in MC according to the sex of the students, specifically in the dimension Object Control, where the boys present a better motor performance in these tasks than the girls. By contrast, no significant differences were noted between the two groups in the dimension Self-Movement. Regarding the time of MVPA, the analyses revealed differences between boys and girls, with the boys presenting more minutes of daily activity in this range of intensity. In addition, most children do not manage to reach to complete the recommendations of 60 min daily of MVPA. In that sense, the children who comply with the recommendations of 60 min of MVPA daily present higher MC values in the dimension Object Control than those who do not, whereas in the dimension Self-Movement, the two groups do not differ. This highlights the need to implement strategies that develop MC and promote PA programs both at school and beyond, offering more alternatives for participation that can stimulate adherence to the regular practice of PA.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Universidad de La Frontera Scientific Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

NM-L: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. IE: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing. PC-C: Writing – original draft, Writing – review & editing. NA-F: Methodology, Writing – original draft, Writing – review & editing. JC-O: Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Aguilar-Farías, N., Martino-Fuentealba, P., Infante-Grandon, G., and Cortinez-O'Ryan, A. (2017). Inactividad física en Chile: debemos responder al llamado global. *Rev. Med. Chile* 145, 1631–1632. doi: 10.4067/s0034-98872017001201631

Aguilar-Farias, N., Miranda-Marquez, S., Toledo-Vargas, M., and Chandia-Poblete, D. (2021). Comparison between self-reported and accelerometer-derived measurements for classifying children and adolescents as physically active in Chile. *Cad. Saude Publica* 37:e00240620. doi: 10.1590/0102-311X00240620

Aubert, S., Barnes, J. D., Demchenko, I., Hawthorne, M., Abdeta, C., Abi Nader, P., et al. (2022). Global matrix 4.0 physical activity report card grades for children and adolescents: results and analyses from 57 countries. *J. Phys. Act. Health* 19, 700–728. doi: 10.1123/jpah.2022-0456

Barnett, L. M., Lai, S. K., Veldman, S. L. C., Hardy, L. L., Cliff, D. P., Morgan, P. J., et al. (2016). Correlates of gross motor competence in children and adolescents: a systematic review and Meta-analysis. *Sports Med.* 46, 1663–1688. doi: 10.1007/s40279-016-0495-z

Barnett, L. M., Webster, E. K., Hulteen, R. M., de Meester, A., Valentini, N. C., Lenoir, M., et al. (2022). Through the looking glass: a systematic review of longitudinal evidence, providing new insight for motor competence and health. *Sports Med.* 52, 875–920. doi: 10.1007/s40279-021-01516-8

Bermúdez-Ferrales, M., Poblete-Valderrama, F., Morilla Castro, C., and Quintana Figueroa, C. (2015). Nivel de desarrollo motor grueso en pre-escolares sin intervención de profesores de educación física, Valdivia. *Rev. Horiz.* 6, 33–42. doi: 10.29035/rcaf.19.1.8

Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J. D., et al. (2019). Motor competence levels and developmental delay in early childhood: a multicenter cross-sectional study conducted in the USA. *Sports Med.* 49, 1609–1618. doi: 10.1007/s40279-019-01150-5

Calahorro-Cañada, F., Torres-Luque, G., López-Fernández, I., and Carnero, E. A. (2015). Análisis fraccionado de la actividad física desarrollada en escolares. *Rev. Psicol. Deporte* 24, 1–7,

Carcamo-Oyarzun, J., and Herrmann, C. (2020). Validez de constructo de la batería MOBAK para la evaluación de las competencias motrices básicas en escolares de educación primaria. *Rev. Esp. Pedagog.* 78, 291–308. doi: 10.22550/REP78-2-2020-03

Carcamo-Oyarzun, J., Herrmann, C., Gerlach, E., Salvo-Garrido, S., and Estevan, I. (2023). Motor competence, motivation and enjoyment in physical education to profile children in relation to physical activity behaviors. *Phys. Educ. Sport Pedagogy*. 1–16. doi: 10.1080/17408989.2023.2265399

Carcamo-Oyarzun, J., Peña-Troncoso, S., and Cumilef-Bustamante, P. (2022). Validez de contenido de la batería MOBAK para la evaluación del eje curricular de habilidades motrices en Educación Física. *Estud. Pedagog.* 48, 309–322. doi: 10.4067/S0718-07052022000100309

Ceppi-Larraín, J., Chandía-Poblete, D., Aguilar-Farías, N., and Cárcamo-Oyarzún, J. (2021). Relación entre el cumplimiento de las recomendaciones de actividad física y de sueño y el exceso de peso en escolares de la ciudad de Temuco, Chile. *Arch. Argent. Pediatr.* 119, 370–377. doi: 10.5546/aap.2021.eng.370

Crane, J. R., Naylor, P. J., Cook, R., and Temple, V. A. (2015). Do perceptions of competence mediate the relationship between fundamental motor skill proficiency and physical activity levels of children in kindergarten? *J. Phys. Act. Health* 12, 954–961. doi: 10.1123/jpah.2013-0398

Duncan, M. J., Roscoe, C. M., Noon, M., Clark, C. C., O'Brien, W., and Eyre, E. L. (2020). Run, jump, throw and catch: how proficient are children attending English schools at the fundamental motor skills identified as key within the school curriculum? *Eur. Phys. Educ. Rev.* 26, 814–826. doi: 10.1177/1356336X19888953

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., and McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *J. Sports Sci.* 26, 1557–1565. doi: 10.1080/02640410802334196

Glinkowska, B., and Glinkowski, W. M. (2018). Association of sports and physical activity with obesity among teenagers in Poland. *Int. J. Occup. Med. Environ. Health* 31, 771–782. doi: 10.13075/ijomeh.1896.01170

Gonzalez-Huenulef, Y., Martino-Fuentealba, P., Bretz, K., Ferbol, C., and Carcamo-Oyarzun, J. (2023). Competencia motriz real y percibida en niños y niñas de la Patagonia Chilena: La percepción del estudiantado y del profesorado de Educación Física. *Retos* 50, 290–297. doi: 10.47197/retos.v50.99781

Grissom, R. J. (1994). Probability of the superior outcome of one treatment over another. *J. Appl. Psychol.* 79, 314–316. doi: 10.1037/0021-9010.79.2.314

Guthold, R., Stevens, G. A., Riley, L. M., and Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. *Lancet Child Adolesc. Health.* 4, 23–35. doi: 10.1016/S2352-4642(19)30323-2

Gutierrez-Hervas, A., Cortés-Castell, E., Juste-Ruíz, M., and Rizo-Baeza, M. (2020). ¿Qué variables influyen en el cumplimiento de las recomendaciones de actividad física en preescolares? *An. Pediatr.* 92, 156–164. doi: 10.1016/j.anpedi.2019.05.017

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., and Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 380, 247–257. doi: 10.1016/S0140-6736(12)60646-1

Herrmann, C., Heim, C., and Seelig, H. (2016). Construct and correlates of basic motor competencies in primary school-aged children. *J. Sports. Health Sci.* 8, 63–70. doi: 10.1016/j.jshs.2017.04.002

Herrmann, C., and Seelig, H. (2017). Basic motor competencies of fifth graders. *Ger. J. Exerc. Sports Res.* 47, 110–121. doi: 10.1007/s12662-016-0430-3

Holfelder, B., and Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: a systematic review. *Psychol. Sport Exerc.* 15, 382–391. doi: 10.1016/j.psychsport.2014.03.005

Iivonen, S., and Sääkslahti, A. K. (2014). Preschool children's fundamental motor skills: a review of significant determinants. *Early Child Dev.Care.* 184, 1107–1126. doi: 10.1080/03004430.2013.837897

Li, J. C.-H. (2016). Effect size measures in a two independent-samples case with non-normal and non-homogeneous data. *Behav. Res. Methods* 48, 1560–1574. doi: 10.3758/s13428-015-0667-z

Lima, R. A., Pfeiffer, K., Larsen, L. R., Bugge, A., Moller, N. C., Anderson, L. B., et al. (2017). Physical activity and motor competence present a positive reciprocal longitudinal relationship across childhood and early adolescence. *J. Phys. Act. Health* 14, 440–447. doi: 10.1123/jpah.2016-0473

Logan, S. W., Kipling Webster, E., Getchell, N., Pfeiffer, K. A., and Robinson, L. E. (2015). Relationship between fundamental motor skill competence and physical activity during childhood and adolescence: a systematic review. *Kinesiol. Rev.* 4, 416–426. doi: 10.1123/kr.2013-0012

Lopes, L., Santos, R., Coelho-E-Silva, M., Draper, C., Mota, J., Jidovtseff, B., et al. (2020). A narrative review of motor competence in children and adolescents: what we know and what we need to find out. *Int. J. Environ. Res. Public Health* 18. doi: 10.3390/ijerph18010018

Luarte, R. C., Poblete, V. F., and Flores, R. C. (2014). Nivel de desarrollo motor grueso en preescolares sin intervención de profesores de educación física, Concepción, Chile. *Rev. Cs. Act. Fís. UCM.* 15, 7–16,

Martínez Martínez, J., Contreras Jordán, O. R., Aznar Laín, S., and Lera Navarro, Á. (2012). Niveles de actividad física medido con acelerómetro en alumnos de 3° ciclo de Educación Primaria: actividad física diaria y sesiones de Educación Física. *Rev. Psicol. Deporte.* 21, 117–123,

Martinez-Lopez, N., Espinoza-Silva, M., and Carcamo-Oyarzun, J. (2021). Competencia motriz en escolares de primer y segundo año de primaria en la región de Araucanía, Chile. *Pensar. En. Mov.* 19:e45621. doi: 10.15517/pensarmov.v19i2.45621

Müller, C., Candia-Cabrera, P., Casas-Sotomayor, F., and Carcamo-Oyarzun, J. (2022). La competencia motriz real y percibida en contexto de ruralidad según el sexo y la participación deportiva extraescolar. *Cuad. de Psicol. del Deporte.* 22, 268–281. doi: 10.6018/cpd.482421

Ortega-Benavent, N., Menescardi, C., Carcamo-Oyarzún, J., and Estevan, I. (2024). ¿La percepción de competencia y alfabetización motriz median la relación entre la competencia motriz y la práctica de actividad física? *Rev. Psicodidact*. doi: 10.1016/j.psicod.2024.02.001

Quintriqueo-Torres, J., Menares-Quiroz, D., Aguilar-Farias, N., Salvo-Garrido, S., and Carcamo-Oyarzun, J. (2022). Differences in motor competence of Chilean schoolchildren according to biological and sociocultural correlates. *Children* 9:1482. doi: 10.3390/children9101482

Quitério, A., Martins, M., Martins, J., Onofre, M., Gerlach, E., Scheuer, C., et al. (2017). Educação Física: Avaliação das competências motoras em alunos de seis anos, do primeiro ano de escolaridade. *Retos* 31, 259–263,

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., et al. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Med.* 45, 1273–1284. doi: 10.1007/s40279-015-0351-6

Rodríguez-Briceño, D., Castro-Vilugrón, F., Díaz-Alvarado, M., and Carcamo-Oyarzun, J. (2021). La competencia motriz en estudiantes chilenos de 3° y 4° de educación básica. Aprendizajes esperados versus realidad. *Retos* 44, 515–524. doi: 10.47197/retos.v44i0.91095

Scheuer, C., Bund, A., and Herrmann, C. (2019). Diagnosis and monitoring of basic motor competencies among third-graders in Luxembourg. An assessment tool for teachers. *Meas. Phys. Educ. Exerc. Sci.* 23, 258–271. doi: 10.1080/1091367X.2019.1613998

Silva-Santos, S., Santos, A., Martins, C., Duncan, M., Lagoa, M. J., Vale, S., et al. (2021). Associations between motor competence, moderate-to-Vigorous physical activity, and body mass index among preschoolers over 1 year. *J. Phys. Act. Health.* 18, 832–837. doi: 10.1123/jpah.2020-0356

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., et al. (2008). A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest* 60, 290–306. doi: 10.1080/00336297.2008.10483582

Strotmeyer, A., Kehne, M., and Herrmann, C. (2020). Motorische Basiskompetenzen. *Ger. J. Exerc. Sports Res.* 50, 82–91. doi: 10.1007/s12662-019-00596-z

Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., and Raitakari, O. (2005). Physical activity from childhood to adulthood: a 21-year tracking study. *Am. J. Prev. Med.* 28, 267–273. doi: 10.1016/j.amepre.2004.12.003

Temple, V. A., Crane, J. R., Brown, A., Williams, B.-L., and Bell, R. I. (2016). Recreational activities and motor skills of children in kindergarten. *Phys. Educ. Sport Pedagog.* 21, 268–280. doi: 10.1080/17408989.2014.924494

Thivel, D., Tremblay, M. S., Katzmarzyk, P. T., Fogelholm, M., Hu, G., Maher, C., et al. (2019). Associations between meeting combinations of 24-hour movement recommendations and dietary patterns of children: a 12-country study. *Prev. Med.* 118, 159–165. doi: 10.1016/j.ypmed.2018.10.025

Toledo-Vargas, M., Perez-Contreras, P., Chandia-Poblete, D., and Aguilar-Farias, N. (2020). Compliance of the 24-hour movement guidelines in 9- to 11-year-old children from a low-income town in Chile. *J. Phys. Act. Health* 17, 1034–1041. doi: 10.1123/jpah.2019-0672

Tudor-Locke, C., Barreira, T. V., and Schuna, J. M. (2015). Comparison of step outputs for waist and wrist accelerometer attachment sites. *Med. Sci. Sports Exerc.* 47, 839–842. doi: 10.1249/MSS.0000000000000476

Tyler, R., Mackintosh, K. A., Foweather, L., Edwards, L. C., and Stratton, G. (2020). Youth motor competence promotion model: a quantitative investigation into modifiable factors. *J. Sci. Med. Sport* 23, 955–961. doi: 10.1016/j.jsams.2020.04.008

Utesch, T., and Bardid, F. (2019). "Motor competence" in *Dictionary of sport psychology: Sport, exercise, and performing arts*. ed. D. Hackfort (Cambridge: Academic Press, Elsevier), 186.

Wälti, M., Sallen, J., Adamakis, M., Ennigkeit, F., Gerlach, E., Heim, C., et al. (2022). Basic motor competencies of 6- to 8-year-old primary school children in 10 European countries: a cross-sectional study on associations with age, sex, body mass index, and physical activity. *Front. Psychol.* 13:804753. doi: 10.3389/fpsyg.2022.804753

Wang, W.-Y., Hsieh, Y.-L., Hsueh, M.-C., Liu, Y., and Liao, Y. (2019). Accelerometer-measured physical activity and sedentary behavior patterns in Taiwanese adolescents. *Int. J. Environ. Res. Public Health* 16:4392. doi: 10.3390/ijerph16224392

World Health Organization. (2020). WHO guidelines on physical activity and sedentary behaviour, Available at: https://www.who.int/publications/i/item/9789240015128 (Accesed January 15, 2024).

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Cornerball: a new alternative sport proposal for school physical education

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Physical Education has had to evolve and change throughout history to adapt to the demands of society. As a result, teachers have had to seek pedagogical alternatives to ensure that students are active, motivated, and engaged in the classroom. This approach allows for the development of motor, cognitive, and socio-emotional skills in students, ultimately contributing to the holistic development of the individual, which is the primary goal of education. Out of this intrinsic need for Physical Education, Alternative Sports have emerged, providing opportunities for different types of learning compared to more traditional sports. Cornerball, a hybrid between split-court and wall-based sports, played in a somewhat unique playing area—a 90° corner, is introduced with the aim of offering a new Alternative Sport. The objective of this descriptive study is to present a new pedagogical proposal designed for the educational context, highlighting its characteristics and fundamental aspects to consider, such as rules, the playing field, participants, and methodological strategies for its implementation within a Physical Education classroom. Therefore, the aims and purposes of this work are to describe a new sports game so that in the future, more detailed and specific empirical studies can be proposed.

KEYWORDS
alternative sports, cornerball, physical education, participation, game

1 Introduction

The Physical Activity (PA) configures a mechanism of great importance for today's society. It contributes to raising awareness about the significance of movement in the well-being and health of the population. Through an active and healthy lifestyle, potential pathologies in the youngest can be prevented, obtaining benefits not only for physical health but also for psychological and behavioral aspects among students (1, 2). To achieve this, the educational system relies on a powerful tool: Physical Education (PE).

Over the past few years, PE has undergone modifications in its curricular elements (3) to become a more comprehensive model, adapting to modern times and addressing the educational needs posed in the 21st century (4). To adjust to these changes and requirements, PE teachers must seek new formulas to motivate their students, adapting basic content in their classes, such as motor skills or games and sports (5).

The primary purposes of the PE area within our country's educational system encompass physical-motor development, the creation and recreation of physical culture, and the comprehensive development of individuals (4); To achieve these aims, an element such as games is available. Games are understood as human activities that undergo modifications depending on the society or culture in which they develop. Through games, students expand their knowledge via physical-motor, cognitive, affective-emotional learning, teamwork, and value education (6–9). Similarly, play holds a very valuable cultural value from the perspective of those who engage in it, making it a powerful tool for Physical Education teachers to achieve holistic child development (10, 11). Given that sociomotor sports, containing a social component, fit perfectly into Physical Education classes, they foster valuable attitudes and social skills (10).

On the other hand, sport is considered one of the primary tools within PE to achieve its pedagogical objectives (12). Educational sport is one of the basic and most developed contents in PE (13). It should distance itself from high-performance sports by reducing competitiveness (14), focusing on transmitting values, and reinforcing regular practice of physical-sporting activity among students (15, 16).

However, certain sports considered "traditional," characterized by excessive competition or regulation, fail to motivate students (17–19). In the same line, Gil-Madrona et al. (10) note that popular sports activities are very present in a child's motor biography, making it less likely to surprise and motivate them in PE classes. Therefore, alternative, inclusive, and challenging sports should be proposed to achieve maximum student participation, regardless of their abilities (20–22). From this necessity, arise sports known as "alternative sports" (AS). AS lacks a universally accepted definition due to a lack of standardization of their peculiar and individual characteristics encompassing all of them (23). AS share common elements such as active student participation, value transmission, flexible regulations, and the use of innovative, original, and alternative equipment (24–26), sidelining competitiveness and results to be more appealing to students (27).

Therefore, Feu (24) recommends the inclusion of this type of sport in PE classes. They describe it as a more educational approach since all students start from the same level of knowledge about the game and a more equal motor competence to generate new motor situations and, consequently, new learning.

Consequently, AS could be defined as those departing from the standard using physical-sporting practice, alternative materials, facilities, etc., as fundamental elements to achieve educational objectives and value transmission, enhancing student motivation, emphasizing cooperation over competition, thus promoting healthy lifestyle habits and an active lifestyle (13, 28, 29).

On the other hand, classifying these sports is somewhat complicated because, depending on their understanding, the type of sport, implements to use, time, participation, etc., various classifications exist, such as those by Ellis (30), Almond (31), or Méndez-Giménez (32), among others.

To locate this new proposal, Méndez-Giménez's (32) classification, a modification of Almond's proposal in (31), will be used. It proposes classifying sports into: invasion sports, wall or barrier sports, divided court sports, striking and fielding sports, moving target sports, and fixed target sports with or without opposition.

2 Alternative sports in physical education

The AS arise from the need to foster "sports for all," diverging from the traditional archetype dictated by the requirements in high-performance sports and federative guidelines, wherein only those with better physical abilities fit (33). Consequently, AS prioritize cooperation, values, satisfying experiences, and, notably, the promotion and practice of PA (13). Furthermore, they modify rules or norms, as well as structural elements of traditional sports, to achieve comprehensive student development (27, 34).

Contemporary society demands the application of methodologies, adequate resources, training … in short, seeking alternatives to ensure that learning resonates with students and, thereby, achieve comprehensive individual development (35). Teachers design their sessions based on their experiences, training, available facilities… (36). Therefore, similar to other authors (25), it is proposed and defended to utilize AS in the educational context.

The application of different sports, termed "alternative," yields a series of benefits supported and confirmed in scientific literature. Firstly, they provide physical benefits by increasing physical-sporting activity during the play of certain alternative sports compared to traditional ones (37–40). Additionally, concerning co-education and gender equality, through Quidditch (41, 42) or Korfball (43, 44), it has been demonstrated that social stereotypes decrease, providing more opportunities than other more traditional sports. Along the same lines, through Pinfuvote, it has been shown to contribute to the development of sporting attitudes and values, cooperation, teamwork, and, of course, healthy lifestyle habits (45–48).

Moreover, increased physical activity has been found in co-educational classes, with girls' participation standing out in playing Korfball (49) and Kinball (40). Related to this, students have preferred co-educational orientation in PE classes (50). Conversely, in other studies, it has been demonstrated that boys practice more in the sports field, regardless of the type of sport (51).

Furthermore, it has been evidenced that the use of an alternative sport vs. a traditional one favors student participation and motivation in PE classes (13, 52), additionally enhancing aspects related to involvement and motivation when applying teaching models like the Sports Education Model (SEM) (53).

Due to the surge of AS in the Physical Education classroom such as Ringol (20), Twincon (22), Goubak (21), Unihoc (29), Pickleball [Barranca-Martínez, Hernández-Beltrán, & Gamonales (54)], Brokenball (55), or Artzkirol (56) among others, the following is proposed in this document: to describe and detail the characteristics of a new alternative sport to be used in Physical Education classes and thereby achieve the acquisition of new learning and motor behaviors. Since, in each different game situation, one can appreciate the operation of different logics based on the structure of the game, its internal logic, or the possible relations of cooperation or opposition (57). Therefore, split-court sports have highlighted the constant interaction among players, thus promoting the development of cognitive and tactical skills. Likewise, wall and court sports challenge spatial perception and foster quick decision-making in the face of unpredictable rebounds. Hence, this proposal is highly suitable for generating motor learning by blending skills from both sports and utilizing key aspects of both types of sports.

However, in physical education, there are other sporting alternatives, ambivalent and with optimal playability, such as motor triads, which are those sports games that intermix 3 opposing teams, generating the phenomenon of the paradox of being able to cooperate with one team at a specific moment of the game or, on the contrary, oppose and collaborate with the opponent (58, 59). This alternative also holds high educational value by fostering communication among participants to achieve the teaching-learning process (60) and involving decision-making processes with a playful sense (61).

2.1 Pedagogical justification

As current legislation on Primary Education (62), states, "*one of the objectives of Physical Education at this educational stage is the approach to cultural manifestations of a motor nature and the development of all decision-making processes involved in the resolution of motor situations*" (62).

To achieve this, the execution of motor actions in different situations and spaces will allow the development of motor, cognitive, affective, and social skills.

To address this, the educational curriculum for Primary Education (ages 6–12) includes a content block entitled "*Problem-solving in motor situations*", with a transdisciplinary approach aimed at developing individual, cooperative, oppositional, and collaboration-opposition motor actions (62), within which the proposal of this sport, Cornerball, is framed. We highlight:

Block C "Problem-solving in motor situations" (62).

- Decision making: Coordination of actions with peers in cooperative situations. Adjustment of action to the opponent's location in motor situations of pursuit and interaction with a mobile object.
- Perceptual-motor abilities in practice context: integration of body schema; body awareness; laterality and its projection in space; eye-foot and eye-hand coordination; static and dynamic balance.
- Conditional capacities: basic and resultant physical capacities (coordination, balance, and agility).

Furthermore, it presents another block, named "*Emotional self-regulation and social interaction in motor situations*", which focuses on the development of social skills and the promotion of constructive and inclusive relationships among participants in these motor contexts (62). We highlight:

Block D "Emotional self-regulation and social interaction in motor situations" (62).

- Social skills: verbalization of emotions derived from interaction in motor contexts.
- Respect for game rules.
- Concept of sportsmanship.

Concept of fair play or "sportsmanship". Similarly, legislation regarding Compulsory Secondary Education (12–16 years) also divides the Physical Education subject into the same content blocks (62).

Block C is also referred to as "Problem Solving in Motor Situations," and Block D as "Emotional Self-regulation and Social Interaction in Motor Situations" (62).

Just like in Primary Education, the contents of these blocks are also suitable for development through our sport. We list the following:

Block C "Problem Solving in Motor Situations" (62):

- Decision-making: Group guidelines to optimize the group's motor resources for resolving the action/task in cooperative situations. Adapting one's own movements to the actions of the opponent in opposition situations.
- Delimitation of prior attack and defense strategies based on the characteristics of the team members in collaboration-opposition motor situations involving pursuit and interaction with a mobile object.
- Conditional capacities: development of basic physical capacities.
- Specific motor skills associated with technique in physical-sporting activities.

Block D "Emotional Self-regulation and Social Interaction in Motor Situations" (62):

- Emotional self-regulation: Mood control and failure management strategies in motor situations.
- Respect for rules: Fair play at different levels of sport and physical activity.
- Identification and rejection of behaviors contrary to coexistence in motor situations.

3 Cornerball: description of the proposal

Cornerball is presented as a hybrid recreational-sporting modality that blends two very characteristic types of sports: court-divided sports and wall sports. Both share common principles; they aim to send the mobile object to an opponent's area to gain an advantage or prevent its correct return (63).

Specifically, court-divided sports involve players positioned face-to-face, separated by a net (line, rope, or a "dead" zone), aiming to send the object over it to gain an advantage or hinder the opponent's return (64). Similarly, wall sports involve sending an object against a wall, exchanging hits indirectly (after contact with the wall), making it challenging for the opponent to return (64).

The shared principles between these two sports include alternative participation (no possession dispute over the object), opposition (one or more opponents with opposing intentions), spaces (separated in court-divided games or shared in wall sports where the wall is crucial for gameplay), game objectives (making the object touch the ground twice or having the opponent take it out of the field boundaries), the object itself (varying in sizes or materials), or the use of implements (utilizing one or both body segments) (64, 65).

Moreover, the sporting gesture of hitting (defensive and offensive) is a common technical element in both sports (64). In terms of shared tactical aspects, there is a need to send the object to a distant area of the field (66), move the opponent to a specific zone, leaving the field open, or exploit the opponent's weaknesses (64).

This document aims to showcase the development and implementation of a new alternative sport by modifying the main variables that make up the general structure of sports games (object, implements, net, spaces, time, players, and rules) (64).

3.1 Cornerball court

3.2.1 Playing field

- The playing field consists of two walls forming a 90-degree angle.
- The playing area is delimited by an arc, drawn from wall to wall with an 8 m radius measured from the vertex formed by the two walls and the ground.
- The no-bounce zone after the serve is set at 2 m.
- The total area of the playing field is 50.26 square meters.
- The court is divided into 2 halves of 45 degrees by a net.
- The lines marking the arc (baseline), the no-bounce line, and the vertical line (wall) at the end of the field will be 5 cm wide and white.

3.2.2 Net

- The net spans 8 m from the angle formed by both walls, dividing the field into 2 halves of 45 degrees.
- The net is suspended at 0.85 m above the ground, rising at its ends to a maximum of 0.90 m.
- The net is suspended using a metal cable with a maximum diameter of 0.01 m, connected at its ends to a pole that can have a maximum height of 0.85–0.95 m and can be anchored to the ground for national or international competitions. Alternatively, at the vertex between the two vertical walls, the net can be connected to a hook at 0.85–0.90 m.
- For initial sports training or facilities not specifically prepared for Cornerball, the poles can be mobile and supported on the ground with horizontal supports.
- The net poles are positioned so that their outer surfaces align with the edges of the baseline and the corner. These poles may have a circular or square shape, but they must have rounded corners. Also, the pole placed in the corner must have a corner-shaped support foot to fit without obstructing the game (Figure 1).
- The net is finished with an upper band of 0.05 m width in white, and the cable securing the net runs through its interior.
- The net must be fully extended to occupy the entire space between the poles and the court surface, leaving no space between the net's ends and the poles.
- The threads will be made of artificial fibers, and the mesh size will be small enough to prevent the ball from passing through.

3.2 Cornerball materials

For the development of Cornerball, specific characteristics for the ball and paddle are necessary (Figures 2, 3).

The ball will be made of soft rubber, with a uniform surface in a striking color. Its dimensions should range between 5 cm and 6 cm in diameter (Ø), weighing between 45 and 50 g.

The paddle consists of two parts: the head and the handle in a single body. The paddle material should be rigid, non-compressible, such as plastic, layers of fiberglass, and/or carbon, providing stiffness and comfort. Additionally, the striking surface will be the same on both sides, which may be flat, smooth, or textured. It must have a non-elastic cord or strap for wrist attachment at the end of the handle as a safety precaution, which must be mandatory:

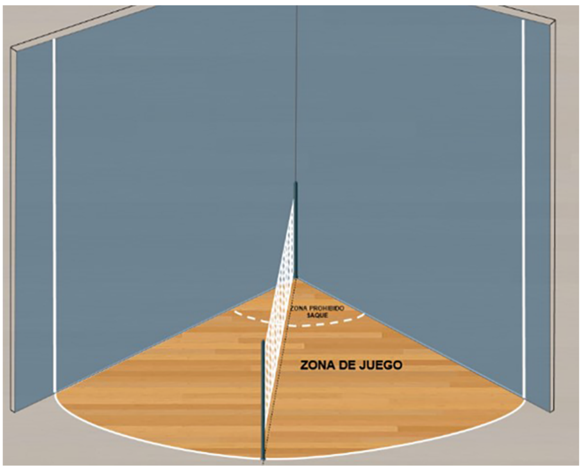

FIGURE 1
Playing field. Perspective 1.

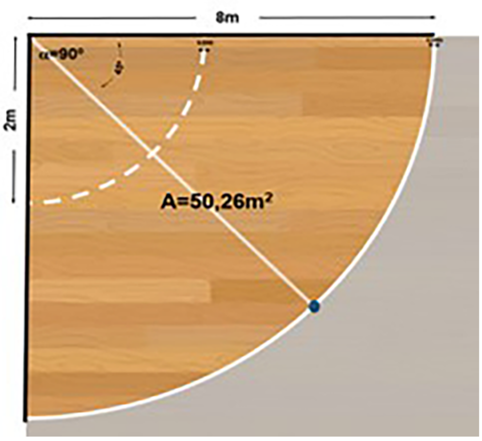

FIGURE 2
Playing field. Perspective 2.

- Handle: The handle will have a length of 12 cm–15 cm, a width and thickness of 3 cm–5 cm.
- Head: The head's length, added to the handle's length, should not exceed 40 cm. It will have a maximum width of 18 cm–20 cm and a maximum thickness of 10 mm–15 mm.
- Weight: The weight will depend on the material used in construction.

3.3 Cornerball participants

Cornerball is an inclusive and innovative alternative sport in which athletes can compete individually or in pairs, although the preferred mode is mixed pairs.

Each pair of players will position themselves on each side of the net, located on opposite ends of the court. The player initiating the ball into play serves (server), and the one responding is the receiver (receiver).

The receiving player can position themselves anywhere in their court, as can their partner and the partner of the server, except during the serve when all 4 players must be outside the court.

Additionally, player participation must alternate; when a player hits and sends the object to the opposing court, they must immediately step back to allow their partner to take over the playing space. Furthermore, except during the serve, players can position themselves wherever they deem suitable for gameplay.

3.4 Cornerball regulation

3.4.1 Rule 1: scoring system

The scoring system in Cornerball operates as follows: there is no time limit, and the match consists of 3 sets of 15 points, without a points advantage. The first team to win two sets wins the match. The unique aspect of the scoring system in this new alternative sport is that both teams start at 15 points, and the first to reach zero wins.

FIGURE 3
Cornerball net.

3.4.2 Rule 2: the serve

The court sides will be determined by a draw before the match begins, and sides will change after each set. The first serve of each set always starts from the left side of the court, facing the corner.

(a) The serve is executed from behind the baseline, bouncing once inside the court.
(b) During the serve (see Figure 5), the ball must be at waist level or below, and the player must keep at least one foot in contact with the ground.
(c) After the serve, the ball needs to hit the wall on the serving player's side of the court. Once it touches that wall, it must bounce off the opposite wall and cross the "no bounce zone" area (see Figure 4) for the point to continue.
(d) While serving, the player cannot walk, run, or jump. Small foot movements that do not affect the initial position are allowed.
(e) The serve is considered made the moment the ball is hit or attempted to be hit, even if unsuccessful.
(f) The team that has the right to serve for the first point of each set decides which of its members will start the serve. The serving rights always belong to the team that lost the previous point, preventing consecutive winning serve points, as the winning team gives the serve to the opposing team. Also, the serve alternates between the members of the pair as long as the point is lost.
(g) The serving player must not serve until the receiving player is ready. However, the receiving player must adapt to a reasonable pace set by the server and be ready to receive the serve when the server is ready to execute it.

3.4.3 Rule 3: service fault

(a) The serving player fails to hit the ball at all in their attempt.

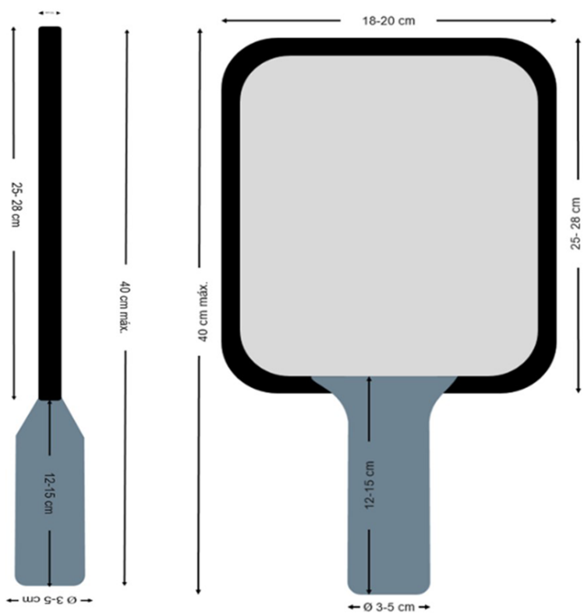

FIGURE 4
Cornerball paddle.

FIGURE 5
Cornerball ball.

(b) The ball bounces out of the reception area or within the "no bounce zone," including the lines that define this area (the lines are considered in play).
(c) The ball hits the server, their partner, or any object they carry.
(d) If the ball, after hitting the double wall, touches the net before bouncing in the opposing court, it's considered a let, and the serve point is repeated.

3.4.4 Rule 4: the return of service

(a) The receiving player must wait for the ball to bounce within their service reception area and hit it before it touches the ground a second time.
(b) The pair receiving the serve for the first point of each set will decide which of the two will start the return. Subsequently, there will be an alternating returner, mirroring the server's pattern. The last player to intervene in the winning team cannot return the serve. This avoids individual matchups during the set.
(c) If the ball hits the player receiving the serve or their partner, or if they touch it with the paddle before it hits the ground, a point is awarded to the serving team.

3.4.5 Rule 5: ball in play

The ball is considered in play from the moment it is hit by the serving player until the referee calls let or decides the point, passing the serve to the corresponding team. Players must alternate hitting the ball.

3.4.6 Rule 6: interference

Interference in the game occurs when a player intentionally or unintentionally impedes or obstructs the opponent's hit. In the former case, the point is awarded to the opponent, and in the latter, the point is replayed.

If the in-play ball hits an object not part of the game, such as another ball or any external element on the opponent's court, it is considered interference, and the point is replayed.

3.4.7 Rule 7: lost point

A player or pair will lose a point if:

(a) A player, their paddle, or any object they carry touches any part of the net, including the posts, or the opposing court while the ball is in play.
(b) The ball bounces twice on the court before being returned by the corresponding player.
(c) The ball bounces out of the court boundaries, both vertically and horizontally.
(d) The ball is hit with a body part other than the paddle.
(e) The ball is hit more than once by a player before touching the wall (double hit).
(f) The net, paddle, clothing, or any body part touches it after hitting the ball.
(g) The ball bounces on their own court before touching the wall.
(h) The ball fails to touch both walls (own and opposing) before bouncing in the opposing court.
(i) The ball hits their wall, the opposing wall, and returns to their own court without bouncing first in the opposing court.
(j) During the serve, the player steps on the line or the court.
(k) During the serve, the ball doesn't bounce inside the court before being hit by the serving player.
(l) Only one player of the pair can hit the ball during the return. If both players simultaneously or consecutively hit the ball, they will lose the point.
(m) The player commits a fault on their first serve.
(n) The paddle is not held by the player at the time of the hit.

3.4.8 Rule 8: won point. ULE 8

(a) If the ball, after bouncing in the opposing court, cannot be returned correctly by the opponent, the point is awarded to the player or pair that made the winning shot.
(b) If the hit ball touches both walls, bounces in the opposing court, and returns to the same court from where it was hit, the point goes to the player who made the hit.
(c) If the ball bounces in the opposing reception area and touches the net before the second bounce or the opponent's hit.

3.4.9 Rule 9: double point

It's possible to score 2 points if the ball is hit before it touches the ground (volley), bouncing off both walls and achieving a point by hitting one's wall, the opposing wall, and then double bouncing in the opponent's court. In all other instances, the scored point will be 1.

3.5 Cornerball: behavior and discipline

Each competitor must maintain respectful and courteous behavior at all times while in the setting of any competition, even if not actively playing, showing consideration toward all individuals present. It is prohibited for players to forcefully throw the paddle or ball in any direction outside the court or execute an aggressive pass across the net when the ball is not in play.

In the same vein, both coaches and players must uphold appropriate behavior, understanding that penalties imposed by referees during the match will accumulate. Once the match commences, the game must proceed without interruptions, and no player can delay it without a valid reason that exceeds the established time limits.

Furthermore, aggressive behaviors, attitudes, and gestures contrary to the sportsmanship spirit from players, especially when directed at the Chief Umpire, referee, opponents, teammates, spectators, or anyone involved in the tournament, will be considered verbally abusive conduct. This encompasses insults and any oral expression implying evident disdain or mockery, even if not a direct insult.

Any violation of these mentioned aspects during the match will be penalized by the tournament's Chief Umpire according to the following classification:

- First offense: Warning (yellow card).
- Second offense: Warning with point loss (orange card).
- Third offense: Warning with disqualification (red card).

It's important to note that infractions committed by both members of the pair, and even their accredited coach, will be cumulative. Furthermore, the Competition Committee may impose additional penalties for the same incident as per the Sports Discipline Regulations.

In cases of extremely serious infractions, such as physical or severe verbal aggression, the Judge/Referee has the authority to immediately disqualify the player or coach responsible for the offense. If disqualification occurs during a match, the player will lose the match and must exit the competition. If the disqualification involves a coach, captain, or registered and accredited player in the tournament, they will be disqualified and must leave the competition.

3.6 Cornerball: methodoloy strategies

In order to implement the teaching of Cornerball in physical education classrooms, a series of methodological strategies are proposed for its instruction. One of the primary strategies to teach Cornerball involves utilizing small-sided games, mini-games, or task-oriented play, facilitating the acquisition of technical-tactical actions for all students, including those less skilled (67).

Additionally, increasing the height of the net can slow down the game, aiding in reaction time and enabling the recovery of optimal playing positions (68).

Furthermore, the Teaching Games for Understanding (TGfU) model by Bunker and Thorpe (69) could be employed, aiming to teach this new activity where students comprehend how to play and solve real game situations. This begins with modified and simple rules to ensure game continuity, adapting them to the psycho-physical characteristics of individuals (64). This approach allows students to assimilate and understand the nuances of the new activity. It helps foster tactical thinking and an awareness of game situations, as well as develop an appropriate language to express these situations (70).

Devís and Peiró (71) suggest that adaptable materials in racket sports play a crucial role. For instance, using a larger or lighter ball can reduce the speed of the game until students acquire sufficient skills to transition to standard equipment (68). Other elements that can be modified, aside from equipment, include playing without a net, using paddle rackets, allowing for double bounces, among others.

Moreover, another available methodological strategy for teaching and motivating students in this proposed activity is the Sport Education model proposed by Siedentop (72, 73). This model organizes the structure akin to a sports season. Students are organized into teams, fostering a sense of belonging to a group, instilling values of group cohesion, and acquiring social competencies and skills. Additionally, it involves a temporal organization with a competition schedule and a record of actions performed by the students.

4 Conclusions

Physical Education, much like the educational system, must progress, change, and adapt to the shifts and advancements occurring in today's society. Employing new methodologies, resources, or innovative teaching approaches to motivate students and capture their attention during classes is crucial. This ensures they can undergo an adequate teaching-learning process and, consequently, acquire the necessary knowledge to navigate contemporary society. It is from this need that Alternative Activities (AAs) emerge as a key content to teach in Physical Education (PE), fostering the holistic development of individuals.

Thus, the alternative sport Cornerball is presented as a game directly applicable within physical education classes. This sport enables the exploration of diverse motor situations and various social contexts.

Cornerball not only contributes to physical and motor benefits but also enhances fundamental physical capacities. It develops perceptual-motor abilities by addressing spatial-temporal control and bodily coordination, foundational elements supporting overall coordination and equilibrium.

Ultimately, there's an expressed need for further research and interventions in Physical Education classes to demonstrate the utility of these alternative sports. This aims to underscore the necessity of integrating them into the teaching-learning process to facilitate the acquisition of new knowledge and skills.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

PD-F: Conceptualization, Data curation, Investigation, Writing – original draft, Writing – review & editing. BR-L: Formal Analysis, Methodology, Writing – original draft, Writing – review & editing. DR-C: Data curation, Formal Analysis, Resources, Software, Writing – original draft. AR-C: Formal Analysis, Funding acquisition, Methodology, Project administration, Validation, Writing – original draft. SL-G: Conceptualization, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Ortega FB, Ruiz JR, Castillo M. Actividad Física, condición física y sobre peso en niños y adolescentes: evidencia procedente de estudios epidemiológicos. *Endocrinología y Nutrición*. (2013) 60(8):458–69. doi: 10.1016/j.endonu.2012.10.006

2. Yanci J, Vinuesa A, Rodriguez J, Yanci L. El tiempo de compromiso motor en las sesiones de Educación Física del primer y segundo ciclo de Educación Primaria. *J Sports Sci*. (2016) 2(2):239–53. doi: doi: 10.17979/sportis.2016.2.2.1447

3. Rodríguez-Torres AF, Chicaiza-Peneida LE, Cusme-Torres AC. Metodologías emergentes para la enseñanza de la Educación Física. *Olimpia*. (2022) 19(1):98–115.

4. López-Pastor V, Pérez-Brunicardi D, Manrique-Arribas JC, Monjes-Aguado R. Los restos de la Educación Física del Siglo XXI. *Retos: Nuevas tendencias en Educación Física, Deportes y Recreación*. (2016) 29:182–97. doi: 10.47197/retos.v0i29.42552

5. Moya-Mata I, Ros-Ros C, Menescardi-Royuela C. Los contenidos de educación física a través de las imágenes de los libros de texto en educación primaria. *Apunts: Educación Física y Deportes*. (2014) 118(4):40–7. doi: 10.5672/apunts.2014-0983.es.(2014/4).118.04

6. Devís J. El juego en el currículum de la Educación Física: aproximación crítica (o el reino de lo posible en la postmodernidad). *Revista Educación Física y Deporte*. (2008) 27(2):79–89. doi: 10.17533/udea.efyd.2249

7. García-Puchades W, Chiva-Bartoll Ó. El juego como proceso de subjetivación y su justificación en el currículum de educación física. *Cultura, Ciencia y Deporte*. (2018) 13(38):147–56. doi: 10.12800/ccd.v13i38.1070

8. Labiak O, Taques MJ, Ribeiro-Honorato IC. Esportes alternativos badminton e mini tênis: experiências no contexto do ensino médio. *Lecturas: Educación Física y Deportes*. (2018) 22(236):32–6.

9. Ladino PK, González-Correa CH, González-Correa CA, Caicedo JC. Ejercicio físico e inteligencia emocional en un grupo de estudiantes universitarias. *Revista Iberoamericana de Psicología del Ejercicio y el Deporte*. (2016) 11(1):31–6.

10. Gil-Madrona P, Pascual-Francés L, Jordá-Espi A, Mujica-Johnson F, Fernández-Revelles AB. Afectividad e interacción motora en juegos motores populares en la escuela. *Apunts Educación Física y Deportes*. (2020) 139:42–8. doi: 10.5672/apunts.2014-0983.es.(2020/1).139.06

11. Mendoza M, Analuiza E, Lara L. Los juegos populares y su aporte didáctico en las clases de educación física. *EmásF Revista Digital de Educación Física*. (2017) 44:70–93.

12. Ferrer A. Análisis de la reforma de Thomas Arnold a través del concepto de función moralizadora de Hernández Álvarez, JL (1996): El deporte moderno y la génesis del movimiento olímpico. *Citius, Altius, Fortius: Humanismo, Sociedad y Deporte: Investigaciones y Ensayos*. (2012) 5(1):119–30.

13. Robles J, Robles A. La participación en las clases de educación física la ESO y Bachillerato. Un estudio sobre un deporte tradicional (Balonmano) y un deporte alternativo (Tchoukball). *Retos: Nuevas Tendencias en Educación Física, Deporte y Recreación*. (2021) 39:78–83.

14. Requena Ó. Juegos alternativos en educación física: flag football. *Revista Digital Innovación y Experiencias Educativas*. (2008) 4(3):1–10.

15. Jaquete C, Ramírez E. Datchball y Colpbol como recursos para promover la inteligencia interpersonal: Experiencia didáctica aplicada con chicas y chicos de Educación Secundaria. *Retos Nuevas tendencias en Educación Física, Deportes y Recreación*. (2021) 42:470–7. doi: 10.47197/retos.v42i0.86991

16. López A, Vega C. Tendencias contemporáneas de la clase de educación física. Cuadernos IMCED. Serie Pedagógica (2000).

17. Caldevilla-Calderón P, Zapatero-Ayuso JA. Los deportes alternativos como contenidos para la Educación Física en Educación Secundaria. *Retos: Nuevas tendencias en Educación Física, Deportes y Recreación*. (2022) 46:1004–14. doi: doi: 10.47197/retos.v46.94422

18. Escamilla A, Alguacil M, González-Serrano MH. Variables predictoras de la motivación deportiva en estudiantes de secundaria federados y no federados. *Retos Nuevas tendencias en Educación Física, Deportes y Recreación*. (2020) 38:58–65. doi: 10.47197/retos.v38i38.73551

19. Stidder G, Hayes S. Equity and inclusion in physical education and sport: themes and perspectives for practitioners. In: Stidder G, Hayes S, editors. *Equity and Inclusion in Physical Education and Sport*. London: Routledge (2013). p. 1–16.

20. González-Coto V, Gámez-Calvo L, Hernández-Beltrán V, Gamonales JM. Ringol: Deporte alternativo en inclusivo en el ámbito educativo. *VIREF Revista de Educación Física*. (2022) 11(4):119–31.

21. González-Coto V, Hernández-Beltrán V, Gámez-Calvo L, Gamonales JM. Goubak: deporte de equipo para las clases de Educación Física. *Lecturas: Educación Física y Deportes*. (2022) 27(295):165–79. doi: 10.46642/efd.v27i295.3465

22. González-Coto VA, Hernández-Beltrán V, García-Espino N, Gamonales JM. Twincon: deporte coeducativo e inclusivo. *Logía, educación física y deporte: Revista Digital de Investigación en Ciencias de la Actividad Física y del Deporte*. (2022) 3 (1):28–39.

23. Martínez-Hita F. Nuevos deportes para una nueva Educación Física. *Lecturas: Educación Física y Deportes*. (2018) 23(243):1–10.

24. Feu S. ¿Son los juegos deportivos alternativos una posibilidad para favorecer la coeducación en las clases de Educación Física? *Campo Abierto Revista de Educación*. (2008) 27(2):31–47.

25. Fierro S, Haro A, García V. Los deportes alternativos en el ámbito educativo. E-Motion. *Revista de Educación, Motricidad e Investigación*. (2016) 6:40–8. doi: 10.33776/remo.v0i6.2800

26. López-Corredor A. La iniciación deportiva en la Enseñanza Primaria: Los juegos motores modificados. *Ensayos: Revista de la Facultad de Educación de Albacete*. (2007) 22:127–54.

27. Hernández JM. El valor pedagógico de los deportes alternativos. *Lecturas: Educación Física y Deportes, Revista Digital*. (2007) 12(114):1.

28. Carrillo AF, Granados O, Jiménez-Gómez S. Deporte alternativo: una mirada sociológica ejemplificada desde el Tchoukball. *Revista de Investigación: Cuerpo, Cultura y Movimiento*. (2016) 6(2):183–98. doi: 10.15332/2422474x/4428

29. Hernández-Beltrán V, Gámez-calvo L, Gamonales JM. Unihoc como deporte alternativo en el ámbito educativo. *e-Motion Revista de Educación, Motricidad e Investigación*. (2021) 16:105–18. doi: 10.33776/remo.v0i16.5193

30. Ellis M. *Similarities and differences in games: a system for classification. Paper Presented at the Association Internationale des Ecoles Superieures d'Education Physique Conference*; Rome, Italy (1983).

31. Almond L. Reflecting on themes: a games classification. In: Thorpe R, Bunker D, Almond L, editors. *Rethinking Games Teaching*. Loughborough: Department of Physical Education and Sport Science University of Technology (1986). p. 71–2.

32. Méndez-Giménez A. Modelos actuales de iniciación deportiva escolar. Unidades didácticas sobre deportes de invasión. Wanceulen Editorial (2009).

33. Méndez-Giménez A. Introducción. In: Chamorro C, Miña T, editors. *Deportes Alternativos: Propuestas prácticas de sus creadores para tu clase*. Barcelona: Editorial INDE (2023). p. 9–14.

34. Moreno-Díaz MI, Tapia-Serrano MA, Vaquero-Solís M, Cano-Cañada E, Sánchez-Miguel PA. El deporte colectivo en educación física. Unidad didáctica del COLPBOL. *Revista Española de Educación Física y Deportes*. (2021) 432:101–9. doi: 10.55166/reefd.vi432.971

35. Ruíz JG. Juegos y deportes alternativos en la programación de Educación física escolar. Editorial Deportiva Agonos (1996).

36. Robles J, Abad MT, Castillo E, Giménez FJ, Robles A. Factores que condicionan la presencia de la expresión corporal en la enseñanza secundaria según el profesorado de educación física. *Retos: Nuevas tendencias en Educación Física, Deportes y Recreación*. (2013) 24:171–5. doi: doi: 10.47197/retos.v0i24.34552

37. Colado JC, Juesas A, Campaña F, Giulia F, Bruñó A, Lisón JF, et al. A new racket sport that provokes similar heart rate as soccer and basketball in children. *Med Sci Sports Exerc*. (2017) 49(5S):881. doi: 10.1249/01.mss.0000519388.43785.e1

38. Gargallo P, Juesas Á, Bruño A, Guzmán JF, Lisón JF, Baños RM, et al. Physiological and psychological effects of a new racket sport in children with and without overweight at primary school. *Cultura, Ciencia y Deporte*. (2020) 15 (45):363–75. doi: 10.12800/ccd.v15i45.1514

39. Hall N, McDonald GK, Hay J, Defries D, Pryce R. Effect of activity type on youth physical activity during structured activity sessions. *Health Behav Policy Rev*. (2016) 3 (6):546–56. doi: 10.14485/HBPR.3.6.4

40. Hastie PA, Langevin F, Wadsworth D. Effects of age and experience on physical activity accumulation during kin-ball. *Res Q Exerc Sport*. (2011) 82(1):140–4. doi: 10.1080/02701367.2011.10599731

41. Cohen A, Melton EN, Peachey JW. Investigating a coed sport's ability to encourage inclusion and equality. *J Sport Manag*. (2014) 28(2):220–35. doi: http://dx.cloi.org/10.1123/jsm.2013-0329

42. Cohen A, Peachey JW. Quidditch: impacting and benefiting participants in a non-fictional manner. *J Sport Soc Issues*. (2015) 39(6):521–44. doi: 10.1177/0193723514561549

43. Gubby L, Wellard I. Sporting equality and gender neutrality in korfball. *Sport Soc*. (2015) 19(8-9):1171–85. doi: 10.1080/17430437.2015.1096261

44. Gubby L. Can korfball facilitate mixed-PE in the UK? The perspectives of junior korfball players. *Sport Educ Soc*. (2018) 24(9):994–1005. doi: 10.1080/13573322.2018.1519506

45. de la Fuente EL. *Cooperative learning in the CLIL physical education classroom: a didactic unit about "alternative games" in first grade of mandatory secondary education* (Trabajo Fin de máster). Universidad de Jaén (2020).

46. Herranz-García A. Los deportes alternativos en el deporte escolar [Trabajo Fin de Grado, Universidad de Valladolid] (2013).

47. Míguez Álvarez C. Promoción de la actividad física en educación primaria a través de la educación física. [Trabajo Fin de Grado, Universidad de Sevilla] (2020).

48. Peña Mora EF. El Pinfuvote: una herramienta para el desarrollo de las capacidades coordinativas de una persona con Síndrome de Down. [Trabajo Fin de Grado, Universidad Pedagógica Nacional] (2019).

49. Van Acker R, da Costa FC, De Bourdeaudhuij I, Cardon G, Haerens L. Sex equity and physical activity levels in coeducational physical education: exploring the potential of modified game forms. *Phys Educ Sport Pedagogy*. (2010) 15(2):159–73. doi: 10.1080/17408980902877609

50. Hannon JC, Ratliffe T. Physical activity levels in coeducational and single-gender high school physical education settings. *J Teach Phys Educ*. (2005) 24(2):149–64. doi: 10.1123/jtpe.24.2.149

51. Hannon JC. Physical activity levels of overweight and nonoverweight high school students during physical education classes. *J Sch Health*. (2008) 78(8):425–31. doi: 10.1111/j.1746-1561.2008.00325.x

52. Ruíz JR, Canovas J, Capitán LM, Imbroda J, Candel J. Spiribol: un giro al deporte. *Lecturas: Educación física y deportes*. (2003) p. 64.

53. Méndez-Giménez A, Fernández-Río J, Méndez-Alonso D. Modelo de educación deportiva versus modelo tradicional: efectos en la motivación y deportividad. *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*. (2015) 15 (59):449–66. doi: 10.15366/rimcafd2015.59.004

54. Barranca-Martínez JM, Hernández-Beltrán VL, Gamonales JM. Pickleball. Deporte alternativo para el ámbito educativo. *Lecturas: Educación Física Y Deportes*. (2023) 28(304):146–60. doi: 10.46642/efd.v28i304.3879

55. Barranca-Martínez JM, Hernández-Beltrán V, Gámez-Calvo L, Gamonales JM. Brokenball. Deporte alternativo para el ámbito educativo. *Lecturas: Educación Física y Deportes*. (2023) 28(303):164–77. doi: 10.46642/efd.v28i303.3922

56. Hortiguela D, Pérez-Pueyo A, Herran I. Combinamos reglas y deportes; El Artzkirol. *Tándem Didáctica de la Educación Física*. (2018) 62:71–3.

57. García-Monge A. Construyendo una lógica educativa en los juegos en Educación Física Escolar: El "juego bueno". *Ágora para la educación física y el deporte*. (2011) 13 (1):35–54.

58. Navarro-Adelantado V, Pic M. Gameplay clues for motor interactions in a triad game. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte*. (2021) 21(82):355–74. doi: 10.15366/rimcafd2021.82.010

59. Pic M, Navarro V. Triad communication and specificity of motor games. *Int J Med Sci Phys Activity Sport*. (2017) 17(67):523–39. doi: 10.15366/rimcafd2017.67.009

60. Navarro-Adelantado V, Pic M. La Tríada Motriz Y Su Valor Educativo A Través De Dos Competencias. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte*. (2023) 23(91):482–99. doi: 10.15366/rimcafd2023.91.030

61. Pic M, Navarro-Adelantado V. Signs, paradox, and sporting games in school physical education. *Semiótica*. (2022) (248):153–68. doi: 10.1515/sem-2022-0056

62. Ministerio de Educación y Formación Profesional. Real Decreto 217/2022, de 29 de marzo, por el que se establece la ordenación y las enseñanzas mínimas de la Educación Secundaria Obligatoria. *Boletín Oficial del Estado*. (2022) 77, 30 de marzo de 2022. p. 52–64.

63. Devís J, Peiró C. Nuevas perspectivas curriculares en la Educación Física: La salud y los juegos modificados. INDE (1992).

64. Méndez-Giménez A. Diseño e intencionalidad de los juegos modificados de cancha dividida y muro. *Revista digital Lecturas de Educación Física y Deportes*. (2000) p. 18.

65. Hernández Moreno J. Fundamentos del deporte. Análisis de las estructuras de los juegos deportivos. INDE (1994).

66. Devís-Devís J. *Educación física, deporte y currículum*. Madrid: Visor (1996).

67. Sánchez-Gómez R, Devís-Devís J, Navarro-Adelantado V. El modelo teaching game for understanding en el contexto internacional y español: una perspectiva histórica. *Ágora para la EF y Deporte*. (2014) 16(3):197–213.

68. Thorpe R. Un understanding approach to the teaching of tennis. *Bull Phys Educ*. (1983) 19(1):12–9.

69. Bunker D, Thorpe R. A model for the teaching of games in secondary schools. *Bull Phys Educ*. (1982) 18(1):5–8.

70. Wright J, Forrest G. A social semiotic analysis of knowledge construction and games centred approaches to teaching. *Phys Educ Sport Pedagogy*. (2007) 12 (3):273–87. doi: 10.1080/17408980701610201

71. Devís J, and Peiró C. "Enseñanza de los deportes de equipo: la comprensión en la iniciación de los juegos deportivos" in *La iniciación deportiva y el deporte escolar*. Ed. Blázquez D. Barcelona: Editorial INDE (1995). p. 333–50.

72. Siedentop D. *Sport Education*. Champaign, Il: Human Kinetics (1994).

73. Siedentop D. What is sport education and how does it work? *J Phys Educ Recreat Dance*. (1998) 69:18–20. doi: 10.1080/07303084.1998.10605528

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What are the important factors influencing the physical activity level of junior high school students: a cross-sectional survey

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Background: Engaging in regular physical activity has been consistently linked to improved physical health and academic performance. Despite its known benefits, there is a concerning trend of decreased physical activity among children globally. The study primarily aims to investigate the level of physical activity among junior high school students in Taiyuan and analyse the main affecting factors from a socio-ecological perspective.

Methods: A cross-sectional study was conducted, involving 650 junior high school students from 7 schools in Taiyuan, and 648 valid questionnaires were ultimately collected. The data on students' physical activity levels were collected through the Children's Leisure Activities Study Survey Questionnaire, and the data on factors affecting students' physical activity were collected through the Student Perceived Factors Affecting Physical Activity Questionnaire.

Results: In this study, students from the 7th, 8th, and 9th grades participated in physical activities, averaging 214.500 min per week in moderate-intensity and 25.000 min in high-intensity activities, cumulatively averaging 280.000 min weekly. Notably, a significant disparity ($p = 0.012$) was observed in the combined duration of moderate and high-intensity activities, with male students engaging more time compared to their female counterparts (307.500 vs. 255.000 min). This variance extended across different grades, particularly evident in 8th graders who recorded the highest weekly high-intensity activity duration (31.000 min) and overall physical activity time (320.500 min), surpassing the 7th graders($p = 0.007$ for high-intensity activities). Furthermore, an exploratory factor analysis of a 32-item questionnaire, designed to identify determinants of physical activity, revealed six principal components. These components were found to positively correlate with both moderate and high-intensity physical activities.

Conclusion: Results emphasize that educational institutions and community programs should collaborate to offer engaging weekend physical activity programs. Schools should develop and implement tailored physical education curricula addressing gender and grade differences. Furthermore, schools and local governments should invest in high-quality sports equipment and facilities.

KEYWORDS

physical activity level, energy consumption, influencing factors, junior high school students, social ecology

1 Introduction

Physical fitness and health are paramount for the growth and development of adolescents (1). This importance is underscored by a growing body of research that links active lifestyles during adolescence with reduced risk of chronic diseases such as type 2 diabetes and cardiovascular disorders later in life (2). Regular physical activity during these formative years not only promotes physical well-being but also impacts mental health, academic performance, and social development (3). Adequate physical activity in this crucial phase lays the groundwork for lifelong health and well-being (4). Despite the clear benefits, the decline in PA among adolescents over the past decade presents a complex challenge influenced by a blend of social, environmental, and psychological factors (5). However, recent trends have sparked concerns regarding the physical health of adolescents, emerging as a pressing global issue (6). Rapid urbanization and technological advancements have contributed to a more sedentary lifestyle among this young population. According to surveys conducted in Europe and the United States, only about 15% (7) and 18.4% (8) of adolescents meet recommended levels of PA, respectively. Moreover, Herman's research indicates that a mere 16% of adolescents maintain active physical behavior into adulthood (9). These alarming statistics highlight an urgent need for targeted interventions that can effectively address the barriers to PA specific to this age group. Unlike younger children or adults, junior high school students are in a critical transition phase, experiencing rapid physical growth, hormonal changes, and cognitive development. This period is pivotal for instilling lifelong health and fitness habits. As a result, the question of how to effectively address the declining trend in physical fitness among junior high school students remains a central issue drawing substantial attention in the realms of modern education and sports.

Previous research has indicated that the diminishing physical health of adolescents is the result of a prolonged impact from various factors (10). Among these factors, the lack of PA is widely recognized domestically and internationally as the primary cause of this decline (11). PA refers to any bodily movement produced by skeletal muscles that requires energy expenditure (12). Studies have shown that regular participation in moderate- and high-intensity physical activities offers numerous health benefits for children and adolescents, including weight management, prevention of obesity, enhanced lipid profiles, metabolic syndrome mitigation, reduced blood pressure, and improved mental well-being (13). Moreover, adopting healthy PA patterns during adolescence not only promotes growth and development but also has lasting effects into adulthood, significantly contributing to the prevention of chronic diseases and the deceleration of aging processes (14). Patnode CD and Lytle LA's research reveals that PA is influenced by several critical factors (15). Socioeconomic status, for instance, plays a significant role, as it affects access to recreational facilities and equipment. Environmental factors, such as the availability of safe and accessible spaces for exercise, also greatly influence PA levels (15). Furthermore, psychological elements like motivation and personal attitudes towards health and fitness can drive or deter adolescent participation in physical activities (16). Family and peer influences are also crucial, as support from these groups can encourage regular engagement in exercise (17). Additionally, educational institutions play a pivotal role by integrating physical education into their curriculum and promoting an active lifestyle among students (18). Furthermore, to improve the physical health of adolescents, many countries have established guidelines for youth PA, with many recommending that children and adolescents engage in at least 60 min of moderate- to high-intensity PA on a daily basis (19, 20). These guidelines reflect a growing consensus on the need for comprehensive strategies that extend beyond school-based programs to include community and policy initiatives that support physical activity among youth.

Despite considerable advancements in PA research at both domestic and international levels, the predominant body of literature primarily resides in the domains of medicine and sports science. This literature mainly employs methods such as heart rate monitoring (21) and pedometers (22) to assess students' PA levels, examining their relationships with various chronic diseases (23) and mental health (23). However, there remains a notable gap in comprehensive research that considers the dimensions of time, intensity, types of physical activities, and sedentary behavior. Moreover, studies focusing on intervention strategies for PA have predominantly been confined to empirical analyses at the individual level (24). In light of these observations, this study aims to fill these gaps by investigating the PA levels of junior high school students from a socio-ecological perspective. Furthermore, the research analyses key influencing factors to provide evidence for the enhancement of students' PA levels, reduction of obesity rates, and the overall strengthening of their physical health. By considering a range of variables, this study aims to identify the significant factors associated with moderate and vigorous physical activity levels among junior high school students, enhancing our understanding of how various environments and backgrounds influence these activity intensities.

2 Methods

2.1 Study design and setting

To facilitate the survey and ensure the careful monitoring of participants, a cross-sectional study was conducted in Taiyuan City. This involved employing a random stratified cluster sampling method to select junior high school students from six districts: Yingze, Xinghualing, Xiaodian, Jiancaoping, Wanbailin, and others. The sampling frame encompassed seven schools systematically chosen from northern, central, and southern districts to ensure the study's representativeness and fairness. The selection of sample schools and the recruitment of participants occurred between 10 and 14 December 2022, during which informed consent forms were obtained from the participants and their parents.

The study involved a total of 650 students from the first, second, and third grades of junior high school, with the objective of providing a representation of the overall PA levels within this demographic in Taiyuan City. Data collection was conducted in the student activity centres of the selected schools from 15 to 22 December 2022. Throughout the data collection phase, two students were unable to continue participating (1 absence and 1 case of incomplete information), resulting in a final sample of 648 participants. The sample comprised 338 males (52.16%) and 310 females (47.84%), with a grade-level distribution of 34.72% in the 7th grade, 30.86% in the 8th grade, and 34.41% in the 9th grade.

Questionnaire administration was supervised by three class teachers and three research team members in each school. Their responsibilities included ensuring order during the process and providing instructions for completing the questionnaire within a designated 60 min period. Following completion, the questionnaires were collected and handed over to a designated researcher for systematic data analysis. The distribution of students from different schools is detailed in Table 1, highlighting the emphasis on achieving a balanced representation across the study's different regions.

2.2 Participants

The inclusion criteria to participate in the study were as follows: (a) being students in Grades 7, 8, and 9 from junior high schools in Taiyuan, China and (b) not having any disease that would prevent the engagement in PA.

Prior to commencing the study, the schools, as well as the fathers, mothers, and/or guardians, were informed about the objectives of the study. Written informed consent was obtained from all participants or their legal representatives to ensure their voluntary participation. This research received approval from the Ethics Committee of the local institution under No. TYUT2023122202. The basic information regarding the participating students is outlined in Table 2.

2.3 Variables and measures

2.3.1 Physical activity levels

In this study, the PA levels of students were represented by two indicators: PA time and energy expenditure during physical activities. A questionnaire was utilized to collect the above data. Among various questionnaires, considering China's national conditions and the aims of this study, the Children's Leisure Activities Study Survey (CLASS) questionnaire (modified CLASS-C Questionnaire), originally from an Australian university and later revised by scholar Li Haiyan (25), was selected. This is known as the Adolescent Daily Physical Activity Survey. Upon review, it was observed that the revised questionnaire maintained the format of the original version while incorporating changes, Common activities like football, badminton, and walking were retained. Activities that are not commonly participated in by mainland Chinese students, such as rugby, golf, squash, karate, bowling, baseball, and judo, were removed. Instead, they were replaced with activities like jumping, throwing, shuttlecock kicking, broadcast gymnastics, and mat exercises, which are common in physical education classes in Chinese primary and secondary schools. Additionally, sedentary lifestyle activities, such as listening to music, taking phone calls, and artistic creation, were combined. As a result, the final questionnaire encompasses 24 types of moderate- to high-intensity physical activities and 8 types of sedentary behaviors. The questionnaire has been validated and has achieved high reliability and validity, aligning with the cognitive level of Chinese adolescents (26).

In this study, Monday to Friday is explicitly defined as weekdays, while Saturday and Sunday are defined as rest days. Additionally, the measurement of PA levels involves a critically important concept – energy expenditure. Energy expenditure is associated with PA: the more PA one engages in, the greater the energy expenditure, showing a positive correlation. The energy expenditure from PA, represented by the Metabolic Equivalent of Task (MET), is not only closely related to body weight, but as a significant component of total energy expenditure in the human body, it plays a vital role in maintaining energy balance (27). Therefore, this study employed energy expenditure from PA as one of the indicators to reflect the level of PA. The formula used to calculate the energy expenditure of PA is as Eq. 1:

$$E = \frac{(Met - 1) \times 3.5 \times W \times T}{200} \quad (1)$$

E: Energy Expenditure of Physical Activity (kcal); Met: Metabolic Equivalent ml/(kg·min); W:Weight (kg); T:Time (min).

The MET values used in this study primarily derive from Ainsworth et al.'s "Compendium of Physical Activities" (28). Furthermore, after consulting PA experts and reviewing standards set by the American College of Sports Medicine, the intensity of PA was categorized into moderate intensity (4.5 METs) and high intensity (7.5 METs).

2.3.2 Influencing factors of physical activity

In this study, after reviewing the literature and consulting experts, the "Student Perceived Factors Affecting Physical Activity Questionnaire"

TABLE 1 School sample.

Title	Category	Frequency	Percent (%)	Accumulated percentage (%)
Gender	Male	338	52.16	52.16
	Female	310	47.84	100.00
Grade	7th Grade	225	34.72	34.72
	8th Grade	200	30.86	65.59
	9th Grade	223	34.41	100.00
School	1.0	99	15.28	15.28
	2.0	90	13.89	29.17
	3.0	91	14.04	43.21
	4.0	88	13.58	56.79
	5.0	69	10.65	67.44
	6.0	150	23.15	90.59
	7.0	61	9.41	100.00
Total		648	100.0	100.0

TABLE 2 Basic information of participants.

Title	*N*	Mean	S.D.
Age (year)	648	14.347	1.012
Height (cm)	648	164.512	8.449
Weight (kg)	648	53.841	29.552

developed by the Jiangsu Province Student Physical Health Promotion Research Center was chosen as the survey tool (29). The questionnaire is designed based on the content of the Social-Ecological Systems Theory. It references previous research on the factors affecting physical activity, investigating three aspects: the individual level, the interpersonal relationship level, and the school community organization level. The questionnaire employs a 5-point Likert scale for responses and scoring, with "Strongly Disagree", "Disagree", "Uncertain", "Agree", and "Strongly Agree" being scored as 1, 2, 3, 4, and 5, respectively. It captures the subjective experiences of students to understand their different states and levels of experience regarding each aspect. This questionnaire has been tested and achieved high reliability and validity (30).

2.4 Study size

The total in-school population of junior high students in Taiyuan was approximately 100,000 (31). Based on the "Table for Determining Sample Size from a Given Population" (32), the required sample size for the survey was calculated to be 384 students. However, to ensure a representative sample across all six districts of Taiyuan, at least one school was selected from each district, leading to a final sample size of 650 students from three grades. This number significantly exceeds the minimum required sample size of 384, thereby enhancing the study's representativeness and the reliability of its findings.

2.5 Statistical methodology

SPSS 23.0 software was used for statistical analysis. For non-normally distributed data, the median M (P25, P75) was used for representation. The Mann–Whitney test was applied to analyse the differences in PA time and energy expenditure between genders. The Kruskal–Wallis test was utilized to examine variations in PA time and energy expenditure across different grades. An exploratory factor analysis was conducted to assess the dimensions and validity of factors perceived by students to influence PA, employing principal component analysis for extraction and varimax rotation for factor rotation. Pearson correlation analysis was used to examine the relationship between various factors and PA time and energy expenditure. A p-value of less than 0.05 was considered statistically significant.

3 Results

3.1 Physical activity level of students

3.1.1 Physical activity time and energy expenditure

The results about PA time and energy expenditure of students are presented in Table 3. The average time spent in moderate-intensity PA for students was 129.000 min, high-intensity PA was 10.000 min, and the combined moderate- and high-intensity activity time averaged 172.500 min on weekdays. On weekends, the time spent in moderate-intensity PA averaged 70.000 min, high-intensity PA averaged 0 min, and the combined time averaged 90 min, which was lower compared to weekdays where the combined moderate- and high-intensity activity time averaged 172.500 min. Over a week, the time spent in moderate-intensity PA averaged 214.500 min, high-intensity PA averaged 25.000 min, and the combined time averaged 280.000 min, with weekly time spent on moderate-intensity physical activity being higher than that spent on high-intensity activity. The average weekly energy expenditure for moderate-intensity PA was 681 kcal, and for HIPA, it was 147 kcal.

3.1.2 Comparison of physical activity time and energy expenditure based on gender

The results about gender differences in PA time and energy expenditure are presented in Table 4. Non-parametric tests were employed to investigate the differences in weekly moderate-intensity, high-intensity, and combined moderate- and high-intensity PA time among students of different genders. The analysis with the Mann–Whitney U test indicated no significant differences ($p > 0.05$) in moderate-intensity time (Figure 1A) and high-intensity activity time (Figure 1B), showing consistency across genders. However, a significant difference ($p < 0.05$) was observed in combined moderate- and high-intensity activity, with male students having a higher median time (307.500) than female students (255.000).

Non-parametric tests were conducted to examine the differences in weekly moderate-intensity and high-intensity energy expenditure between male and female students. The analysis using the Mann–Whitney U test revealed no significant difference ($p > 0.05$) in high-intensity energy expenditure (Figure 1C), indicating consistency across genders. However, there was a significant difference ($p < 0.05$) in moderate-intensity energy expenditure (Figure 1D), with male students showing a higher median value (772.000) compared to female students (579.000), indicating gender differences in this aspect.

3.1.3 Comparison of physical activity time and energy expenditure based on grades

From Table 5, which illustrates the different time spent in weekly PA by grade, using non-parametric tests, we observed the differences in weekly moderate-intensity, high-intensity, and combined moderate- and high-intensity PA times among students of different grades. The Kruskal–Wallis test showed no significant difference ($p > 0.05$) in moderate-intensity activity across grades, indicating consistency. However, significant differences were observed in high-intensity and combined moderate- and high-intensity activities ($p < 0.05$), suggesting variability across grades. Specifically, 8th grade students showed the highest weekly high-intensity PA time (31.000) and combined moderate- with high-intensity PA time (320.500), compared to 7th grade students who had the least in these categories.

The non-parametric tests revealed significant differences in weekly moderate- and high-intensity energy consumption among students of different grades. The Kruskal–Wallis test showed significant variation ($p < 0.05$) across grades for both types of energy consumption. Specifically, 8th-grade students had the highest median weekly energy expenditure for moderate-intensity (774.000) and

TABLE 3 Physical activity time and energy expenditure.

Time	Title	N	Min.	Max.	Mean	S.D.	Median
Weekday	Moderate-intensity physical activity time (min)	648	0.000	980.000	161.204	142.446	129.000
	High-intensity PA time	648	0.000	980.000	53.199	97.012	10.000
	Moderate- and high-intensity PA time (min)	648	0.000	1410.000	214.403	180.434	172.500
Weekend	Moderate-intensity PA time (min)	648	0.000	2150.000	94.227	123.989	70.000
	High-intensity PA time	648	0.000	1080.000	29.472	74.793	0.000
	Moderate- and high-intensity PA time (min)	648	0.000	2150.000	123.699	149.714	90.000
A week	Moderate-intensity PA time (min)	648	0.000	2950.000	255.431	222.652	214.500
	High-intensity PA time	648	0.000	1735.000	82.671	154.313	25.000
	Moderate- and high-intensity PA time (min)	648	0.000	2950.000	338.102	279.533	280.000
A week	Moderate-intensity energy consumption	648	0.000	15055.000	852.319	942.496	681.000
	High-intensity energy consumption (kcal)	648	0.000	30276.000	554.904	1520.121	147.000

TABLE 4 Comparison of weekly PA time and weekly PA energy expenditure by gender.

	Gender median M (P_{25}, P_{75})		U	z	p-value
	Male (n = 338)	Female (n = 310)			
Moderate-intensity PA time (min)	240.000 (117.5, 350.0)	200.000 (98.8, 341.3)	48732.500	−1.537	0.124
High-intensity PA time (min)	30.000 (0.0, 130.0)	20.000 (0.0, 90.0)	49260.500	−1.373	0.170
Moderate- and high-intensity PA time (min)	307.500 (170.0, 466.3)	255.000 (131.5, 412.0)	46414.500	−2.510	0.012*
Moderate-intensity energy Expenditure (kcal)	772.000 (362.3, 1203.3)	579.000 (292.5, 1019.3)	45048.500	−3.084	0.002**
High-intensity energy expenditure (kcal)	171.000 (0.0, 812.3)	127.500 (0.0, 512.0)	48467.000	−1.720	0.085

* $p < 0.05$, ** $p < 0.01$.

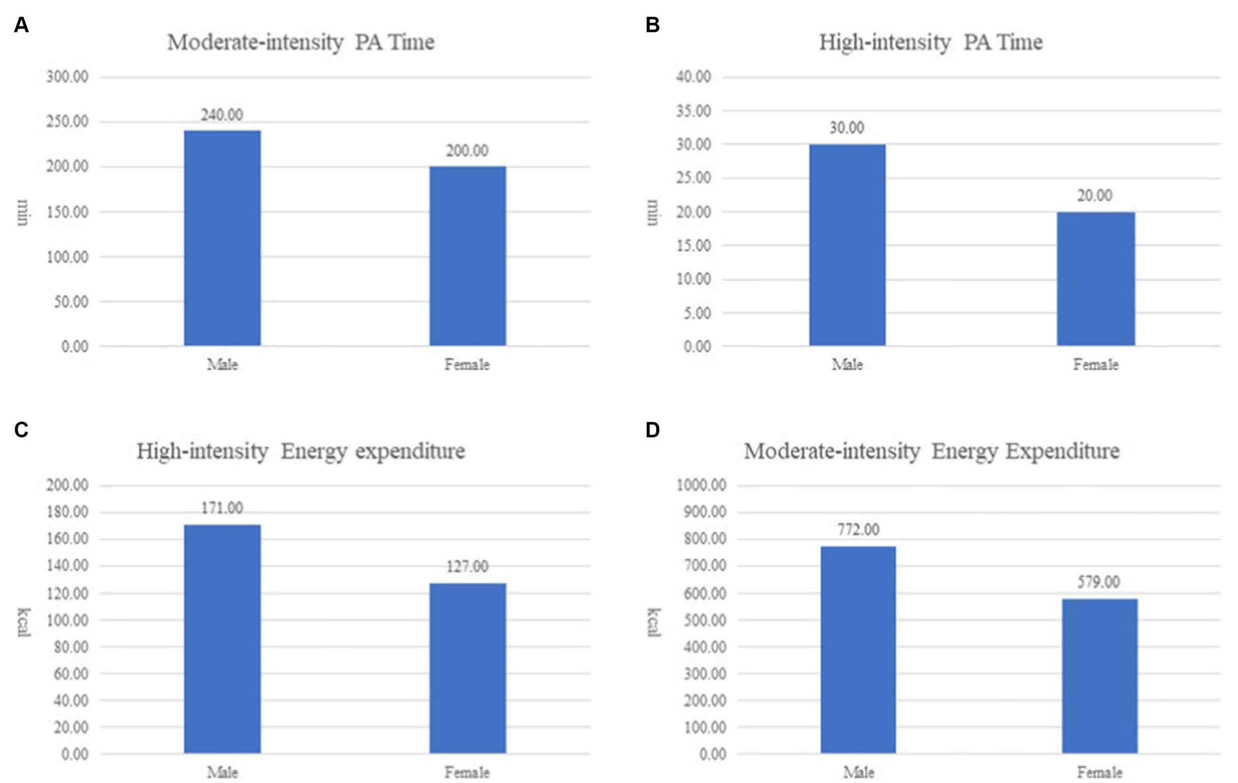

FIGURE 1
(A) Gender differences in moderate-intensity PA time; **(B)** Gender differences in high-intensity PA time; **(C)** Gender differences in high-intensity energy expenditure; **(D)** Gender differences in moderate-intensity energy expenditure.

TABLE 5 Comparison of weekly PA time and weekly energy expenditure by grade.

	Grade median M (P_{25}, P_{75})			H	*p*-value
	7th grade (*n* = 225)	8th grade (*n* = 200)	9th grade (*n* = 223)		
Moderate-intensity PA time	195.000 (100.0, 329.5)	248.000 (100.0, 378.8)	220.000 (110.0, 350.0)	3.446	0.179
High-intensity PA time	0.000 (0.0, 80.0)	31.000 (0.0, 110.0)	30.000 (0.0, 140.0)	9.791	0.007**
Moderate- and high-intensity PA time	240.000 (132.5, 405.0)	320.500 (157.0, 490.0)	295.000 (165.0, 465.0)	9.203	0.010*
Moderate-intensity energy consumption	588.000 (291.0, 945.5)	774.000 (313.8,1212.3)	735.000 (364.0, 1211.0)	8.350	0.015*
High-intensity energy consumption	0.000 (0.0, 405.0)	186.000 (0.0, 651.8)	177.000 (0.0, 802.0)	10.915	0.004**

* $p < 0.05$, ** $p < 0.01$.

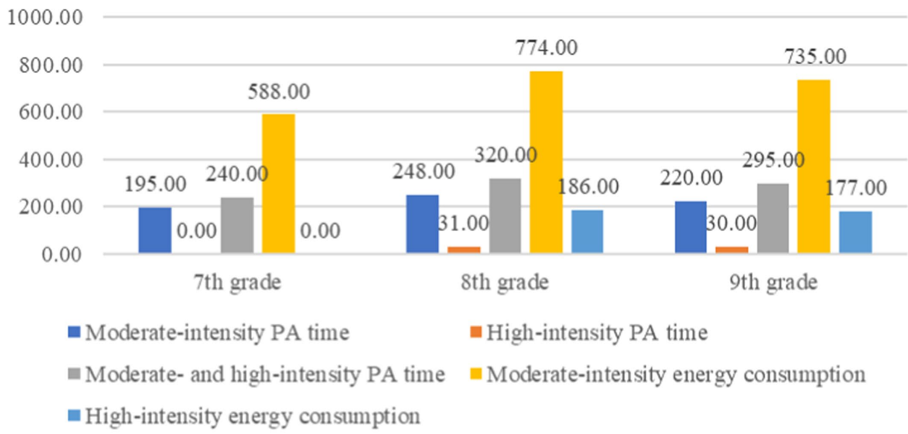

FIGURE 2
Comparison of weekly PA time and weekly energy expenditure by grade.

high-intensity (186.000) activities, whereas 7th-grade students had the lowest in these categories (588.000 and 0.000, respectively).

The non-parametric tests revealed significant differences in weekly moderate- and high-intensity energy consumption among students of different grades. The Kruskal–Wallis test showed significant variation ($p < 0.05$) across grades for both types of energy consumption. Specifically, 8th-grade students had the highest median weekly energy expenditure for moderate-intensity (774.000) and high-intensity (186.000) activities, whereas 7th-grade students had the lowest in these categories (588.000 and 0.000, respectively). We can also see form Figure 2 which clearly showed the comparison of weekly PA time and weekly energy expenditure based on grades.

3.2 Factors influencing students' physical activity levels

The exploratory factor analysis was conducted on the questionnaire assessing the factors influencing students' PA. The results are as follows: Kaiser-Meyer-Olkin = 0.908, indicating good data adequacy for factor analysis. Bartlett's Test of Sphericity resulted in an approximate chi-square of 20718.591 (df = 496, $p < 0.000$), confirming the suitability of the data for factor analysis.

The exploratory factor analysis of the 32-item questionnaire assessing factors influencing PA resulted in the extraction of six principal components, as shown in Table 6. These components, after rotation, accounted for a total cumulative variance of 78.289%. Each factor with an eigenvalue greater than 1 was retained, indicating that these six factors were significant in explaining the variability in the data. The extraction of these six factors demonstrated an effective and substantial interpretation of the original data, with a high cumulative percentage of variance explained.

The factor loading coefficients represented the correlation between factors and analytical items. As shown in Table 7, the rotated factor loadings were significantly greater than 0.4, and most were above 0.7, indicating strong correlations. The commonality of each item, or the common factor variance, was also greater than 0.4, signifying good validity. The distribution of the items across the factors was as follows:

- Items 1–4 correspond to Factor 5, comprising 4 items, and were named "Equipment Support".
- Items 5–10 correspond to Factor 3, comprising 6 items, and were named "School Organization".
- Items 11–16 correspond to Factor 2, comprising 6 items, and were named "Parental and Peer Support".
- Items 17–19 correspond to Factor 6, comprising 3 items, and were named "Class Teacher Factors".
- Items 20–23 correspond to Factor 4, comprising 4 items, and were named "Physical Education Teacher Factors".
- Items 24–32 correspond to Factor 1, comprising 9 items, and were named "Individual Cognition".

This factor structure effectively categorized the various aspects influencing students' perception of PA.

TABLE 6 Total variance explained.

Factor	Eigen			% of variance (unrotated)			% of variance (rotated)		
	Eigen value	% of variance	Cumulative % of variance	Eigen value	% of variance	Cumulative % of variance	Eigen value	% of variance	Cumulative % of variance
1	9.307	29.084	29.084	9.307	29.084	29.084	7.408	23.151	23.151
2	5.539	17.310	46.393	5.539	17.310	46.393	5.204	16.263	39.414
3	3.431	10.720	57.114	3.431	10.720	57.114	3.919	12.245	51.659
4	2.744	8.575	65.689	2.744	8.575	65.689	3.238	10.118	61.777
5	2.347	7.334	73.023	2.347	7.334	73.023	2.645	8.265	70.042
6	1.685	5.266	78.289	1.685	5.266	78.289	2.639	8.247	78.289
7	0.626	1.955	80.244	–	–	–	–	–	–
8	0.581	1.816	82.060	–	–	–	–	–	–
9	0.546	1.706	83.767	–	–	–	–	–	–
10	0.463	1.448	85.215	–	–	–	–	–	–
11	0.444	1.387	86.601	–	–	–	–	–	–
12	0.424	1.325	87.926	–	–	–	–	–	–
13	0.413	1.290	89.216	–	–	–	–	–	–
14	0.378	1.181	90.397	–	–	–	–	–	–
15	0.317	0.992	91.389	–	–	–	–	–	–
16	0.312	0.974	92.362	–	–	–	–	–	–
17	0.293	0.917	93.279	–	–	–	–	–	–
18	0.258	0.807	94.087	–	–	–	–	–	–
19	0.233	0.727	94.813	–	–	–	–	–	–
20	0.214	0.669	95.483	–	–	–	–	–	–
21	0.199	0.621	96.104	–	–	–	–	–	–
22	0.185	0.578	96.682	–	–	–	–	–	–
23	0.180	0.564	97.246	–	–	–	–	–	–
24	0.153	0.479	97.725	–	–	–	–	–	–
25	0.124	0.388	98.112	–	–	–	–	–	–
26	0.120	0.376	98.488	–	–	–	–	–	–
27	0.113	0.354	98.843	–	–	–	–	–	–
28	0.094	0.295	99.138	–	–	–	–	–	–
29	0.077	0.240	99.378	–	–	–	–	–	–
30	0.073	0.228	99.605	–	–	–	–	–	–
31	0.070	0.218	99.823	–	–	–	–	–	–
32	0.057	0.177	100.000	–	–	–	–	–	–

3.3 Correlation between factors and physical activity

The analysis of the relationship between moderate- and high-intensity PA time and six factors (Equipment Support, School Organization, Parental and Peer Support, Class Teacher Factors, Physical Education Teacher Factors, and Individual Cognition) using Pearson correlation coefficients revealed significant findings, as shown in Table 8. At the same time, the Figure 3 also showed the degree of correlation, which is represented by a heatmap (where the redder colors indicate higher correlation and the bluer colors indicate lower correlation):

Moderate-Intensity PA Time: There was a significant positive correlation with all six factors. The correlation coefficients were 0.481 (Equipment Support), 0.141 (School Organization), 0.305 (Parental and Peer Support), 0.199 (Class Teacher Factors), 0.191 (Physical Education Teacher Factors), and 0.189 (Individual Cognition). All coefficients were greater than 0, indicating a positive relationship.

High-Intensity PA Time: This also showed a significant positive correlation with five of the factors, with coefficients of 0.268 (Equipment Support), 0.131 (School Organization), 0.169 (Parental and Peer Support), 0.134 (Physical Education Teacher Factors), and 0.159 (Individual Cognition). However, there was no significant correlation with Class Teacher Factors, as the coefficient was close to 0.

TABLE 7 Factor loading (rotated).

Name	Factor loading						Commonality (common factor variance)
	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	
A1	0.037	0.001	0.060	0.076	**0.791**	0.089	0.645
A2	0.020	0.087	0.021	0.057	**0.852**	0.062	0.741
A3	0.045	0.165	0.055	0.126	**0.753**	−0.021	0.615
A4	0.061	0.143	0.006	−0.038	**0.787**	0.046	0.647
A5	0.011	0.025	**0.760**	0.055	0.061	0.013	0.586
A6	0.014	0.079	**0.826**	0.003	0.014	0.065	0.693
A7	0.057	0.111	**0.771**	0.064	−0.023	0.080	0.621
A8	0.056	0.073	**0.870**	0.042	0.039	0.037	0.770
A9	0.248	0.082	**0.805**	0.023	0.058	0.008	0.721
A10	0.020	0.087	**0.723**	0.045	0.020	0.033	0.534
A11	0.125	**0.908**	0.079	0.170	0.091	0.116	0.898
A12	0.114	**0.922**	0.065	0.118	0.116	0.043	0.896
A13	0.089	**0.882**	0.115	0.160	0.086	0.086	0.839
A14	0.111	**0.930**	0.081	0.117	0.068	0.051	0.904
A15	0.119	**0.900**	0.077	0.117	0.096	0.045	0.855
A16	0.133	**0.809**	0.153	0.197	0.082	0.186	0.776
A17	0.050	0.134	0.084	0.199	0.060	**0.931**	0.937
A18	0.067	0.125	0.092	0.118	0.076	**0.935**	0.923
A19	0.071	0.169	0.062	0.333	0.074	**0.835**	0.852
A20	0.030	0.146	0.055	**0.821**	0.072	0.192	0.741
A21	0.071	0.258	0.023	**0.839**	0.082	0.110	0.796
A22	0.052	0.184	0.083	**0.862**	0.073	0.107	0.804
A23	0.047	0.155	0.073	**0.873**	0.025	0.186	0.829
A24	**0.911**	0.163	0.067	0.027	0.007	0.051	0.865
A25	**0.924**	0.136	0.064	0.036	0.011	0.077	0.884
A26	**0.847**	0.178	0.010	0.064	0.034	0.040	0.756
A27	**0.928**	−0.055	0.020	−0.021	−0.004	−0.012	0.865
A28	**0.805**	−0.014	0.100	0.076	0.045	0.047	0.668
A29	**0.933**	0.080	0.034	−0.011	−0.018	0.031	0.880
A30	**0.894**	0.104	0.043	0.039	0.069	−0.009	0.819
A31	**0.899**	0.075	0.062	0.034	0.077	0.013	0.824
A32	**0.915**	0.136	0.092	0.047	0.044	0.034	0.870

Bold values in the table are all greater than 0.7.

Combined Moderate- and High-Intensity PA Time: There was a significant positive correlation with all six factors. The coefficients were 0.531 (Equipment Support), 0.185 (School Organization), 0.336 (Parental and Peer Support), 0.191 (Class Teacher Factors), 0.226 (Physical Education Teacher Factors), and 0.238 (Individual Cognition), all greater than 0, indicating a positive relationship.

These results suggest that both moderate- and high-intensity physical activities were positively influenced by the mentioned factors, with varying degrees of correlation.

Table 9 presents a correlation analysis exploring the relationships between energy expenditure at moderate and high intensities and six factors (Equipment Support, School Organization, Parental and Peer Support, Class Teacher Factors, Physical Education Teacher Factors, and Individual Cognition) using Pearson correlation coefficients.

Significant positive correlations were found between moderate-intensity energy expenditure and various factors, including Equipment Support (0.362), School Organization (0.106), Parental and Peer Support (0.261), Class Teacher Factors (0.162), Physical Education Teacher Factors (0.153), and Individual Cognition (0.114), all significant at the 0.01 level.

In high-intensity energy expenditure, significant positive correlations were observed with Equipment Support (0.155) and Parental and Peer Support (0.141), both significant at the 0.01 level, and with Physical Education Teacher Factors (0.092), significant at the

TABLE 8 Correlation between different factors and weekly PA time.

	Moderate-intensity PA time	High-intensity PA time	Moderate- and high-intensity PA time
Equipment support	0.481**	0.268**	0.531**
School organization	0.141**	0.131**	0.185**
Parental and peer support	0.305**	0.169**	0.336**
Class teacher factors	0.199**	0.059	0.191**
Physical education teacher factors	0.191**	0.134**	0.226**
Individual cognition	0.189**	0.159**	0.238**

* $p<0.05$, ** $p<0.01$.

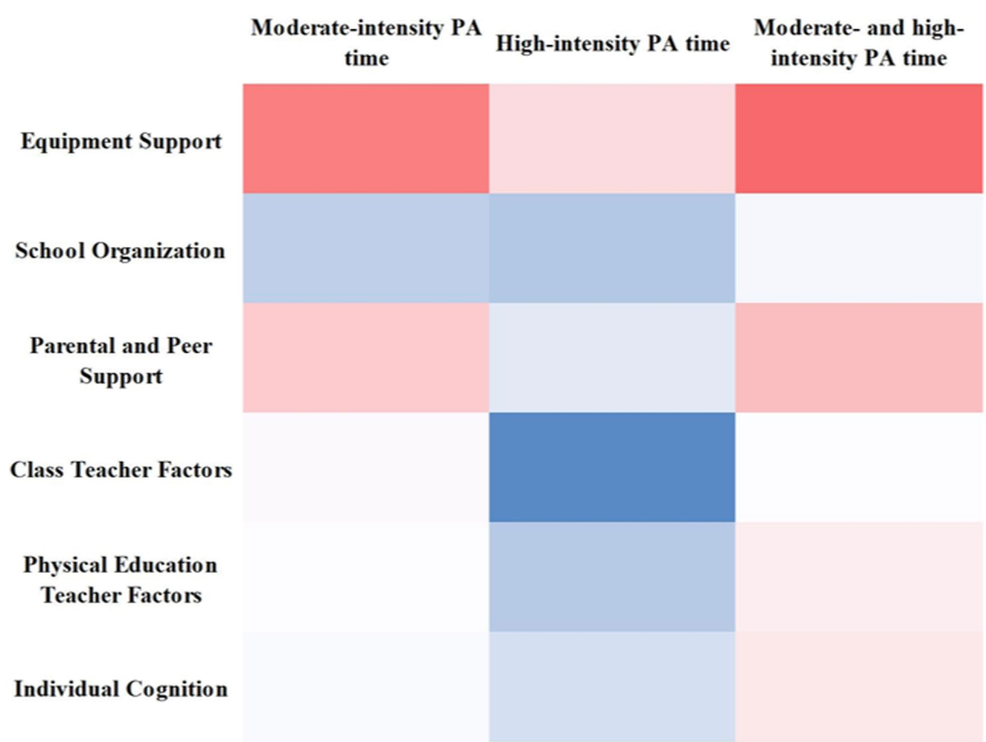

FIGURE 3
The relationships between energy expenditure at moderate and high intensities and six factors (equipment support, school organization, parental and peer support, class teacher factors, physical education teacher factors, and individual cognition).

0.05 level. No significant correlations were found with School Organization, Class Teacher Factors, and Individual Cognition.

4 Discussion

This study revealed the PA levels and influencing factors of 648 junior high school students in Taiyuan City. The findings highlight significant variations in the PA times and energy expenditures of students between weekdays and weekends. Notably, students engaged in more moderate- and high-intensity physical activities on weekdays compared to weekends. This observation may be partially explained by the structured nature of school environments, where scheduled physical education classes and recess promote regular activity during weekdays (33). This pattern aligns with prior research indicating reduced PA among children during non-school days (34). However, the level of high-intensity PA, especially during weekends, is lower throughout the week, which differs from some research results in similar population environments. It is also possible that the availability of parental supervision or participation during weekends varies, affecting the intensity and type of activities students can engage in (35). These differences may be attributed to regional differences in lifestyle, school curriculum, or accessibility to recreational facilities (36). In addition, the daily PA time of students does not meet the World Health Organization's recommended guidelines for physical activities for this age group to engage in at least 60 min of moderate to vigorous PA each day (37), emphasizing the need for targeted interventions to improve PA levels, especially on weekends. Moreover, the discrepancy between actual and recommended PA levels underscores the importance of integrating health education into the school curriculum, ensuring that students understand the benefits of maintaining an active lifestyle.

TABLE 9 Correlation between different factors and weekly energy consumption.

	Moderate-intensity energy consumption	High-intensity energy consumption
Equipment support	0.362**	0.155**
School organization	0.106**	0.071
Parental and peer support	0.261**	0.141**
Class teacher factors	0.162**	0.035
Physical education teacher factors	0.153**	0.092*
Individual cognition	0.114**	0.058

* $p < 0.05$, ** $p < 0.01$.

The comparison of PA time and energy expenditure among junior high school students revealed gender differences. While there is no significant difference in moderate- and high-intensity PA time across genders, a notable disparity exists in the combined moderate- and high-intensity activity time, with boys showing higher levels. This suggests that while the total time spent on physical activities may be similar, boys tend to participate in activities that are more intense or require greater energy output than those typically chosen by girls. Furthermore, a significant difference in moderate-intensity energy expenditure was observed, again favouring boys. These findings highlight gender disparities in PA habits among students, suggesting that boys engage in more prolonged and energetically demanding activities. This contrasts with some studies that report minimal gender differences in activity levels among children, indicating that cultural, environmental, and educational factors might play a role in these disparities (38). These findings underscore the need for gender-specific strategies to promote PA among students.

The results also showed significant grade-based differences in PA time and energy expenditure among the students. While there is no significant disparity in moderate-intensity PA time across grades, substantial differences are noted in high-intensity and combined moderate- and high-intensity activity time, with Grade 8 students showing the highest levels. Additionally, there are significant differences in both moderate- and high-intensity energy consumption among grades, with Grade 8 students also leading in energy expenditure. This can be attributed to several factors, including developmental changes, where Grade 8 students are at a peak growth stage, leading to higher energy and activity levels (39). Furthermore, social factors and peer influence could play a role, as students in this age group may be more motivated to participate in physical activities for social interaction and skill development. Additionally, the competitive environment and peer group dynamics in higher grades may incentivize students to engage more actively in physical activities, particularly as they seek to establish social hierarchies and gain peer acceptance through sports and other physical pursuits (40). The study also found that Grade 9 students have higher levels of PA than Grade 7 students, possibly due to Grade 9 students allocating more time to academic preparations, including physical education tests, which are part of the middle school examination system (41). This shift in focus reflects the impact of national education policies, highlighting the importance of policy-driven changes in student behavior and priorities.

This study utilized exploratory factor analysis to identify factors influencing students' PA. Six principal components are extracted, representing different aspects such as "Equipment Support", "School Organization", and "Individual Cognition". This structure categorizes the various elements impacting students' perception of PA. It is notable that each factor, such as "Parental and Peer Support", shows a strong correlation with specific questionnaire items, underlining the complexity of factors influencing PA among students. Moreover, the interaction between these factors provides insights into the dynamic interplay of environmental, social, and personal influences that shape PA patterns among students. This comprehensive categorization aids in understanding the multifaceted nature of student PA behavior.

The findings also revealed significant positive correlations between various factors and the weekly PA levels of students. Notably, Equipment Support emerges as a consistent and significant factor in influencing moderate- and high-intensity PA time, as well as energy expenditure. This corroborates previous research underscoring the critical role of accessible and quality equipment in promoting physical engagement (42). According to the self-determination theory by Deci and Ryan (43), the presence of high-quality sports equipment may enhance the perceived competence and autonomy among students, which are vital for fostering intrinsic motivation towards engaging in physical activities. In contrast, Class Teacher Factors showed a weaker, albeit still positive, correlation. This could be attributed to the variable influence of classroom teachers on PA, as suggested by Trigueros et al. (44). Interestingly, this factor did not significantly correlate with high-intensity PA, potentially indicating a threshold in the impact of classroom teaching methods on more vigorous forms of exercise. The moderate correlations with Parental and Peer Support, as well as Individual Cognition, highlight the importance of social and psychological elements in PA engagement, as discussed by Haidar et al. (45), who emphasized the role of social and cognitive factors in shaping PA patterns among youth. Furthermore, the influence of School Organization, while significant, is relatively modest. This finding is in partial agreement with previous research (46), which suggested that institutional factors might not be the primary drivers of energy expenditure in physical activities.

Overall, the findings corroborate the existing literature while providing new insights into the differential impacts of various factors on PA intensity. Specifically, the analysis highlights the unique contribution of equipment quality and availability in motivating students. This revelation points to practical applications in school policy where investments in high-quality sports equipment could be prioritized. Furthermore, the interplay between teacher roles and social supports, such as peer and parental encouragement, suggests a multi-faceted strategy is necessary to effectively enhance PA levels among junior high students. Educational programs should not only focus on the physical resources but also on cultivating an encouraging social environment.

4.1 Limitations

This study has several limitations that should be mentioned. Firstly, as a cross-sectional study, this research involved data collection over a brief period, making it challenging to discern causal relationships between PA and its impact on physical fitness, cardiopulmonary endurance, and bone health. The study primarily facilitated a correlation analysis between certain factors. Consequently, future research would benefit from more comprehensive longitudinal tracking studies that explore these relationships in greater depth. Secondly, compared to accelerometers, PA questionnaires provide a more rudimentary measurement and yield less precise data. Therefore, it is recommended that future studies combine accelerometers with questionnaires to enhance measurement accuracy. Thirdly, the analysis of influencing factors in this study is not thorough enough. For instance, motivation is a critical determinant of PA, although it is briefly addressed in this manuscript. Based on the self-determination theory (43), in a recent research by Ahmadi et al. (47), a classification system of motivational behaviors has been proposed. Future research could build on this classification system to further develop and test an intervention program aiming at enhancing motivation towards physical activity levels among adolescents.

5 Conclusion

This study investigated the PA levels and main influencing factors among junior high school students in Taiyuan, providing a theoretical basis for improving the level of PA of students and enhancing the physical fitness of students. The research indicates that students engage more in moderate- and high-intensity activities on weekdays, with a marked decline during weekends. Notably, the daily PA time of students does not meet the World Health Organization's recommended guidelines, especially on weekends. Additionally, the study underscored gender- and grade-based disparities in PA, with boys and Grade 8 students showing higher levels of activity and energy expenditure. This emphasized the need for age- and gender-specific PA guidelines and interventions in schools. Furthermore, the study has identified six key influencing factors of PA among students, including "Equipment Support", "School Organization", "Parental and Peer Support", "Class Teacher Factors", "Physical Education Teacher Factors", and "Individual Cognition", which play important roles in shaping students' PA perceptions and behaviors. In addition, this study underscored the pivotal role of Equipment Support in promoting moderate- to high-intensity physical activities and energy expenditure and highlighted the lesser, yet positive, impact of Class Teacher Factors, alongside the moderate influence of Parental and Peer Support and Individual Cognition. These insights emphasize the importance of a comprehensive approach to physical education, integrating equipment availability, educational practices, and socio-cognitive elements.

5.1 Implications

This study has significant implications for various educational and health-related fields. First, it underscores the urgent need for targeted policies to boost PA during weekends when a marked decline is observed. It is suggested that educational institutions and community programs collaborate to offer engaging weekend PA programs. Second, the highlighted gender- and grade-based disparities call for the development of age- and gender-specific PA guidelines in schools. This suggests that schools should develop and implement tailored physical education curricula that address these differences. Furthermore, the study's identification of six key factors influencing PA emphasizes the necessity of multifaceted interventions. Additionally, the pivotal role of Equipment Support in promoting physical activities cannot be overlooked, necessitating enhanced infrastructure in educational institutions. It is suggested that schools and local governments invest in high-quality sports equipment and facilities. Finally, the study advocates for an integrated approach in physical education, combining equipment availability with educational and socio-cognitive elements, to holistically improve student fitness and engagement in physical activities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Biomedical Ethics Committee of the Academic Committee of Taiyuan University of Technology. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HM: Conceptualization, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. XL: Conceptualization, Data curation, Resources, Supervision, Writing – review & editing. CM: Investigation, Validation, Writing – original draft. DT: Methodology, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

1. Farooq A, Martin A, Janssen X, Wilson MG, Gibson AM, Hughes A, et al. Longitudinal changes in moderate-to-vigorous-intensity physical activity in children and adolescents: a systematic review and meta-analysis. *Obes Rev*. (2020) 21:e12953. doi: 10.1111/obr.12953

2. Alvarez-Pitti J, Casajús-Mallén JA, Leis-Trabazo R, Lucía A, de Lara DL, Moreno-Aznar LA, et al. Exercise as medicine in chronic diseases during childhood and adolescence. *An Pediatr (Engl Ed)*. (2020) 92:173.e1–8. doi: 10.1016/j.anpedi.2020.01.010

3. Collie S, Saggers RT, Bandini R, Steenkamp L, Champion J, Gray G, et al. Association between regular physical activity and the protective effect of vaccination against SARS-CoV-2 in a south African case–control study. *Br J Sports Med*. (2023) 57:205–11. doi: 10.1136/bjsports-2022-105734

4. Cachón-Zagalaz J, Arufe-Giraldez V, Romance-García ÁR, Zagalaz-Sánchez ML. Physical education, schools and lifelong habits. *Front Sports Act Living*. (2023) 5:1180587. doi: 10.3389/fspor.2023.1180587

5. Hu D, Zhou S, Crowley-McHattan ZJ, Liu Z. Factors that influence participation in physical activity in school-aged children and adolescents: a systematic review from the social ecological model perspective. *Int J Environ Res Public Health*. (2021) 18:3147. doi: 10.3390/ijerph18063147

6. Hamdani SMZH, Hamdani SMZH, Zhuang J, Hadier SG, Hadier SG, Khurram H, et al. Establishment of health related physical fitness evaluation system for school adolescents aged 12–16 in Pakistan: a cross-sectional study. *Front Public Health*. (2023) 11:1212396. doi: 10.3389/fpubh.2023.1212396

7. Guinhouya B, Samouda H, De Beaufort C. Level of physical activity among children and adolescents in Europe: a review of physical activity assessed objectively by accelerometry. *Public Health*. (2013) 127:301–11. doi: 10.1016/j.puhe.2013.01.020

8. Kann L. Youth risk behavior surveillance—United States, 2017. *MMWR Surveill Summ*. (2018) 67:1–114. doi: 10.15585/mmwr.ss6708a1

9. Herman KM, Craig CL, Gauvin L, Katzmarzyk PT. Tracking of obesity and physical activity from childhood to adulthood: the physical activity longitudinal study. *Pediatr Obes*. (2009) 4:281–8. doi: 10.3109/17477160802596171

10. Dong B, Zou Z, Song Y, Hu P, Luo D, Wen B, et al. Adolescent health and healthy China 2030: a review. *J Adolesc Health*. (2020) 67:S24–31. doi: 10.1016/j.jadohealth.2020.07.023

11. Haseler T, Haseler C. Lack of physical activity is a global problem. *BMJ*. (2022) 376:o348. doi: 10.1136/bmj.o348

12. Banerjee G, Kumar R, Basu D, Chakraborty SN, Hansda K, Munshi BD. Physical activity pattern and its impact on glycemic control among patients with type-2 diabetes mellitus attending an integrated diabetes and gestational diabetes clinic of eastern India. *Natl J Physiol pharm Pharmacol*. (2019) 10:1. doi: 10.5455/njppp.2020.10.1238622122019

13. Asif I, Thornton JS, Carek S, Miles C, Nayak M, Novak M, et al. Exercise medicine and physical activity promotion: core curricula for US medical schools, residencies and sports medicine fellowships: developed by the American medical Society for Sports Medicine and endorsed by the Canadian academy of sport and exercise medicine. *Br J Sports Med*. (2022) 56:369–75. doi: 10.1136/bjsports-2021-104819

14. Lenze L, Klostermann C, Schmid J, Lamprecht M, Nagel S. The role of leisure-time physical activity in youth for lifelong activity-a latent profile analysis with retrospective life course data. *Ger J Exerc Sport Res*. (2023) 53:1–9. doi: 10.1007/s12662-023-00884-9

15. Patnode CD, Lytle LA, Erickson DJ, Sirard JR, Barr-Anderson D, Story M. The relative influence of demographic, individual, social, and environmental factors on physical activity among boys and girls. *Int J Behav Nutr Phys Act*. (2010) 7:79–10. doi: 10.1186/1479-5868-7-79

16. Palmer K, Robbins LB, Ling J, Kao T-SA, Voskuil VR, Smith AL. Adolescent autonomous motivation for physical activity: a concept analysis. *J Pediatr Nurs*. (2020) 54:e36–46. doi: 10.1016/j.pedn.2020.04.020

17. Kirby J, Levin KA, Inchley J. Parental and peer influences on physical activity among Scottish adolescents: a longitudinal study. *J Phys Act Health*. (2011) 8:785–93. doi: 10.1123/jpah.8.6.785

18. Pérez-Jorge D, González-Luis MA, Rodríguez-Jiménez MC, Ariño-Mateo E. Educational programs for the promotion of health at school: a systematic review. *Int J Environ Res Public Health*. (2021) 18:10818. doi: 10.3390/ijerph182010818

19. Lee J, Zhang T, Chu TLA, Gu X, Zhu P. Effects of a fundamental motor skill-based afterschool program on Children's physical and cognitive health outcomes. *Int J Environ Res Public Health*. (2020) 17:3. doi: 10.3390/ijerph17030733

20. Neil-Sztramko SE, Caldwell H, Dobbins M. School-based physical activity programs for promoting physical activity and fitness in children and adolescents aged 6 to 18. *Cochrane Database Syst Rev*. (2021) 9:CD007651. doi: 10.1002/14651858.CD007651.pub3

21. Nagovitsyn RS, Chelnokova EA, Vaganova OI, Smirnova ZV, Kutepov MM. Calorimetry of students' heart rate during exercises of various intensity. *BIO Web Conf*. (2020) 26:00033. doi: 10.1051/bioconf/20202600033

22. Sartore-Baldwin ML, Das BM. A comparison of undergraduate students' physical activity levels in a standard fitness walking class vs. a service-learning dog walking class. *J Am Coll Health*. (2022) 70:1–7. doi: 10.1080/07448481.2022.2119394

23. Marques A, Peralta M, Martins J, Matos MG, Brownson RC. Cross-sectional and prospective relationship between physical activity and chronic diseases in European older adults. *Int J Public Health*. (2017) 62:495–502. doi: 10.1007/s00038-016-0919-4

24. Balducci S, D'Errico V, Haxhi J, Sacchetti M, Orlando G, Cardelli P, et al. Effect of a behavioral intervention strategy on sustained change in physical activity and sedentary behavior in patients with type 2 diabetes: the IDES_2 randomized clinical trial. *JAMA*. (2019) 321:880–90. doi: 10.1001/jama.2019.0922

25. Biddle SJ, Gorely T, Pearson N, Bull FC. An assessment of self-reported physical activity instruments in young people for population surveillance: project ALPHA. *Int J Behav Nutr Phys Act*. (2011) 8:1–9. doi: 10.1186/1479-5868-8-1

26. Huang Y, Wong SH, Salmon J. Reliability and validity of the modified Chinese version of the Children's leisure activities study survey (CLASS) questionnaire in assessing physical activity among Hong Kong children. *Pediatr Exerc Sci*. (2009) 21:339–53. doi: 10.1123/pes.21.3.339

27. Burridge K, Christensen SM, Golden A, Ingersoll AB, Tondt J, Bays HE. Obesity history, physical exam, laboratory, body composition, and energy expenditure: an obesity medicine association (OMA) clinical practice statement (CPS) 2022. *Obes Pillars*. (2022) 1:100007. doi: 10.1016/j.obpill.2021.100007

28. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, et al. 2011 compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc*. (2011) 43:1575–81. doi: 10.1249/MSS.0b013e31821ece12

29. Dagkas S, Stathi A. Exploring social and environmental factors affecting adolescents' participation in physical activity. *Eur Phys Educ Rev*. (2007) 13:369–84. doi: 10.1177/1356336X07081800

30. Meiyan T. *A study on physical activity and influencing factors of primary and secondary school students in Jiangsu Province [dissertation/master's thesis]*. Jiangsu (IL): Nanjing Normal University (2014).

31. Zhongtian Y, Kai W, Jin L, Guoyu C, Meiqiong W, Jiangtao H, et al. Relationship between chronotype and mental health problems among middle school students in Taiyuan. *Chin J School Health*. (2023) 7:1034–7. doi: 10.16835/j.cnki.1000-9817.2023.07.017

32. Krejcie RV, Morgan DW. Determining sample size for research activities. *Educ Psychol Meas*. (1970) 30:607–10. doi: 10.1177/001316447003000308

33. Gao Z, Chen S, Huang CC, Stodden DF, Xiang P. Investigating elementary school children's daily physical activity and sedentary behaviours during weekdays. *J Sports Sci*. (2017) 35:99–104. doi: 10.1080/02640414.2016.1157261

34. Comte M, Hobin E, Majumdar SR, Plotnikoff RC, Ball GD, McGavock J, et al. Patterns of weekday and weekend physical activity in youth in 2 Canadian provinces. *Appl Physiol Nutr Metab*. (2013) 38:115–9. doi: 10.1139/apnm-2012-0100

35. Ornelas IJ, Perreira KM, Ayala GX. Parental influences on adolescent physical activity: a longitudinal study. *Int J Behav Nutr Phys Act*. (2007) 4:1–10. doi: 10.1186/1479-5868-4-3

36. Kallio J, Hakonen H, Syväoja H, Kulmala J, Kankaanpää A, Ekelund U, et al. Changes in physical activity and sedentary time during adolescence: gender differences during weekdays and weekend days. *Scand J Med Sci Sports*. (2020) 30:1265–75. doi: 10.1111/sms.13668

37. Baran J, Weres A, Wyszyńska J, Pitucha G, Czenczek-Lewandowska E, Rusek W, et al. 60 minutes per day in moderate to vigorous physical activity as a natural health protector in young population. *Int J Environ Res Public Health*. (2020) 17:8918. doi: 10.3390/ijerph17238918

38. Nielsen G, Pfister G, Bo AL. Gender differences in the daily physical activities of Danish school children. *Eur Phys Educ Rev*. (2011) 17:69–90. doi: 10.1177/1356336X11402267

39. Travlos AK. High intensity physical education classes and cognitive performance in eighth-grade students: an applied study. *Int J Sport Exerc Psychol*. (2010) 8:302–11. doi: 10.1080/1612197X.2010.9671955

40. Patel MS, Asch DA, Rosin R, Small DS, Bellamy SL, Eberbach K, et al. Individual versus team-based financial incentives to increase physical activity: a randomized, controlled trial. *J Gen Intern Med*. (2016) 31:746–54. doi: 10.1007/s11606-016-3627-0

41. Gao X. Research on the present situation and optimization strategy of PE teaching under the background of PE middle school entrance examination. *Learn Educ*. (2022) 10:235. doi: 10.18282/l-e.v10i7.3028

42. Delidou E, Matsouka O, Nikolaidis C. Influence of school playground size and equipment on the physical activity of students during recess. *Eur Phys Educ Rev*. (2016) 22:215–24. doi: 10.1177/1356336X15598790

43. Deci EL, Ryan RM. "Self-determination theory," in *Handbook of theories of social psychology*, In: Paul A.M. Van Lange, editor. (Thousand Oaks, CA: Sage Publications Ltd) (2012). 416–36.

44. Trigueros R, Mínguez LA, González-Bernal JJ, Jahouh M, Soto-Camara R, Aguilar-Parra JM. Influence of teaching style on physical education adolescents' motivation and health-related lifestyle. *Nutrients*. (2019) 11:2594. doi: 10.3390/nu11112594

45. Haidar A, Ranjit N, Archer N, Hoelscher DM. Parental and peer social support is associated with healthier physical activity behaviors in adolescents: a cross-sectional analysis of Texas school physical activity and nutrition (TX SPAN) data. *BMC Public Health*. (2019) 19:1–9. doi: 10.1186/s12889-019-7001-0

46. Huang W, Shi X, Wang Y, Li X, Gao P, Lu J, et al. Determinants of Student'S physical activity: a 12-month follow-up study in Ningxia Province. *BMC Public Health*. (2021) 21:512. doi: 10.1186/s12889-021-10525-1

47. Ahmadi A, Noetel M, Parker P, Ryan RM, Ntoumanis N, Reeve J, et al. A classification system for teachers' motivational behaviors recommended in self-determination theory interventions. *J Educ Psychol*. (2023) 115:1158–76. doi: 10.1037/edu0000783

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Developing the optimal gross movement interventions to improve the physical fitness of 3–10 year-old children: a systematic review and meta-analysis

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Objective: To identify the optimal parameters of gross movement interventions to yield the strongest effects on physical fitness among children aged 3–10 years and to provide a reference for the development of gross movement interventions to improve the physical fitness of children.

Background: There has been a global decline in children's physical fitness. Previous studies have shown that gross movement interventions can improve children's physical fitness, but the optimal intervention parameters for achieving the strongest effects have yet to be determined. Therefore, we conducted this meta-analysis to determine the optimal intervention parameters for yielding the strongest effects on children's physical fitness.

Methods: We searched the Web of Science, PubMed, China Biology Medicine, China National Knowledge Infrastructure, Wanfang Data, and China Science and Technology Journal databases to identify randomized controlled trials on the effects of gross movement interventions (walking, running, jumping, throwing, batting, rolling, spinning, catching, and leg lifting) on children's physical fitness (upper-body strength, lower-body strength, explosive power, speed, flexibility, and balance). We included studies published up to September 2023. The inclusion and exclusion criteria were developed based on the PICOS framework, and the quality of the included studies was evaluated. Subgroup analysis was performed using Review Manager 5.3, and the data were pooled using a random effects model to obtain the SMD (or WMD) and 95% confidence intervals (CIs).

Results: A total of 23 studies involving 2007 healthy children aged 3–10 years met the inclusion criteria. Gross movement interventions significantly improved the explosive power of children aged 3–10 years [WMD, 6.2]. The most effective intervention duration was 16–18 weeks [WMD, 0.45]. The most effective intervention frequency was one session per week [WMD, 1.06]. The optimal duration of single sessions was 60 min [WMD, 0.47]. Children aged 7–10 years [WMD, 1.41] showed the most significant improvements in physical fitness after gross movement interventions.

Conclusion: Gross movement interventions had a positive effect on the physical fitness of children aged 3–10 years. The optimal intervention parameters include 60-min sessions once a week across a total duration of 16–18 weeks.

KEYWORDS

gross movement, children, physical fitness, meta-analysis, 3–10 years old

1 Introduction

Physical fitness is a term that comprehensively describes physical performance related to human structure and function (Chen et al., 1993) and includes the following qualities: speed, endurance, strength, coordination, flexibility, and balance (He, 2017; Tao et al., 2017; Kim et al., 2021; Yang et al., 2022). In this study, upper-body strength, lower-body strength, explosive power, speed, flexibility and balance were included as dependent variables. Many studies have confirmed the relationship between children's physical fitness and health. Some studies have shown that improving children's physical fitness can prevent or reduce the risk of obesity and cardiovascular disease (Al-Mallah et al., 2018; Elagizi et al., 2018; Henriksson et al., 2020). Improving children's physical fitness can also lead to long-term health benefits (Smith et al., 2014; Mintjens et al., 2018). However, there has been a global decline in children's physical fitness (Burns et al., 2018; Godoy-Cumillaf et al., 2021; Qu, 2021). According to a new report jointly released by the World Health Organization and the United Nations Children's Fund, there are approximately 317 million cases of physical development disorders among children worldwide (World Health Organization, 2023). In 2022, China issued the Fifth National Physical Fitness Monitoring Communique, and compared with 2014, many physical qualities of Chinese children have shown a downward trend—for example, strength and flexibility decreased by 1.3–6.6% (National Health Monitoring Centre, 2022). In developed countries, the strength of children continues to decline (Tomkinson, 2007), as exemplified by the decreases in muscular strength among children in Sweden and Russia (Malina and Katzmarzyk, 2006) and decreases in upper-body strength (Tremblay et al., 2010) and lower-body strength (Moliner-Urdiales et al., 2010) among Canadian and Spanish children.

Physical fitness and gross movement are the two main aspects of physical performance (Huang, 2000) and are measured from different perspectives to explain physical performance. Physical fitness is a stable external feature of physical performance (Zhou, 2010), while gross movement is the basic foundation of physical performance (Li et al., 2019) and includes the earliest basic motor skills established by children (Wang et al., 2020). Gross movements, which are completed using large skeletal muscle groups (Thomas et al., 2022), mainly include basic motor abilities (e.g., walking, running, jumping, throwing, catching, hitting, kicking, and batting). In this study, walking, running, jumping, throwing, batting, rolling, rotating, catching, and leg lifting were included as independent variables. Gross movement plays a significant role in improving children's physical fitness (Wu et al., 2014; Zhou, 2020) and reducing the risk of obesity and cardiovascular and other health problems in children; therefore, gross movement interventions have become an important parameter for studying children's health promotion in the fields of sports and epidemiology (Okely et al., 2004; Barnett et al., 2008; Robinson et al., 2015; Ma and Song, 2017; Pu and Yang, 2017; Hao, 2018; Li et al., 2019; Wang et al., 2019). Additionally, in recent years, most related studies have focused on examining the correlation between gross movement performance and physical fitness (Foulkes et al., 2021; Liu et al., 2023) or differential performance (Haugen and Johansen, 2018; Zheng et al., 2022) in children, thus confirming the important impact of gross movement interventions on improving children's physical fitness in early development. This positive correlation persists as age increases (Robinson et al., 2015), thus laying the foundation for future exercise ability and fitness levels. Therefore, it is particularly important to consider gross motor development in childhood. However, the optimal parameters for gross movement interventions to yield the greatest improvements in physical fitness among children aged 3–10 years remain unclear.

Three-year-old children perform the most basic physical activities, such as walking and climbing (Xu et al., 2023); they can have the potential to master gross movements at age 6 (O'Brien et al., 2016)and are expected to reach proficiency at age 10 (Ulrich, 2000). However, according to statistics, the gross movement level of 10-year-old children in Germany, China, Brazil and other countries is not ideal. The gross movement level of 10-year-old children worldwide has failed to match the standards for their age group (Xu et al., 2023). Therefore, this study quantified the beneficial effects of gross movement interventions on children's physical fitness, providing theoretical support for further research in this field.

Many countries have adopted the standing long jump, tennis ball long throw, two-foot continuous jumping, 10-meter shuttle run, balance beam walking, and sit-and-reach tests for evaluating children's physical fitness in terms of strength, speed, agility and flexibility (State General Administration of Sport, 2015; Wang, 2022). Although gross movement interventions can effectively improve children's physical fitness, it is still necessary to identify more accurate strategies for children aged 3–10 years to carry out accurate and effective interventions and to fully prepare children for future healthy development. Previous studies have shown that age, intervention duration, and intervention frequency may be significant factors associated with the effect of gross movement interventions on children's physical fitness (Pozuelo-Carrascosa et al., 2018; Utesch et al., 2019; Godoy-Cumillaf et al., 2020; Wu et al., 2021). Therefore, it is very important to accurately identify the optimal parameters for gross movement interventions to yield the greatest improvements in physical fitness among children aged 3–10 years.

Therefore, the purpose of this study was to explore the optimal parameters for gross movement interventions to yield the greatest improvements in physical fitness among children aged 3–10 years and to provide a reference for the development of gross movement intervention programs that aim to improve the physical fitness of children.

2 Methods

2.1 Retrieval strategy

Two researchers conducted a literature search with the following primary search terms: "Physical Fitness AND gross movement AND randomized controlled trial." Additionally, the following secondary search terms were used: "Fitness, Physical OR Physical AND gross action OR gross motor skill OR large muscle action OR basic motor skills OR functional training OR functional game OR functional sports game OR basic movement skills OR function training AND randomized OR toddler OR Child OR childhood OR baby OR primary school OR Kindergarten." The following databases were searched: Web of Science, PubMed, China Biology Medicine, China National Knowledge Infrastructure, Wanfang Data, and China Science and Technology Journal. We included studies from China, the United Kingdom and Mexico. The retrieval time ranged from the establishment of the database to September 2023. If the articles were incomplete or unavailable, we contacted the corresponding authors by email to obtain detailed information. The search initially yielded 3,680 studies on the effects of gross movement interventions on the physical fitness of healthy children aged 3–10 years.

2.2 Inclusion and exclusion criteria

Two researchers independently screened the articles, and disagreements were resolved by consulting a third researcher. The inclusion criteria were developed in accordance with the population, intervention, comparison, outcomes, study design (PICOS) framework. (1) Study subjects: All the subjects were healthy children aged 3–10 years without disease. (2) Intervention measures: The experimental group performed intervention exercises involving gross movements (walking, running, jumping, throwing, batting, rolling, spinning, catching, and leg lifting). (3) Control measures: The control group participated in normal kindergarten or primary school activities without additional intervention. (4) Outcome indicators: All or some of the six outcome indicators, including a 10-m shuttle run, standing long jump, tennis ball long throw, sit-and-reach, two-foot continuous jumping, and balance beam, were included. The outcome data are expressed as the mean ± SD. (5) Study type: The trial design was a randomized controlled trial. The exclusion criteria were as follows: (1) descriptive research, analytical research, conference abstracts and literature reviews; (2) duplicate studies, studies of low quality, and studies of which the full text was not available; (3) studies that did not report the outcomes as the mean ± SD and for which the data could not be converted. The measurement evaluation criteria were scored.

2.3 Data extraction

Two researchers independently extracted the following data according to a predefined protocol: literature name, author, publication time, nationality of subjects, sex, age, total number of subjects, number of experimental groups, number of control groups, intervention measures, intervention duration, single intervention duration, and outcome indicators. For the outcome indicators, the physical fitness test scores before and after each RCT in the experimental group and the control group were recorded. Scores are reported as the mean ± SD. Disagreements were resolved by consulting a third investigator.

2.4 Method quality evaluation

The Cochrane risk of bias tool was used to evaluate the quality of the 23 included studies across seven domains: random allocation method, concealment of allocation scheme, blinding of participants and implementers, blinding of outcome evaluators, integrity of outcome data, selective report results, and other sources of bias. Each domain was rated as "high risk," "unclear risk" or "low risk." Two researchers independently assessed the data. Any disagreements were resolved by consulting a third researcher.

2.5 Statistical analysis

STATA 16.0 was used for the statistical analysis. Since the indicators included in the literature were continuous outcome variables, a random-effects model was used to conduct a meta-analysis based on 6 outcome indicators (sit-and-reach, standing long jump, 10-m shuttle run, tennis ball throw distance, two-foot continuous jumping, balance beam), combined with effect size (WMD or SMD) and 95% confidence intervals. The weighted mean difference (WMD) eliminates the influence of absolute values on the results so that the research results can truly reflect the experimental effect; in addition, it is easy to understand when applied. The standardized mean difference (SMD) not only eliminates the effect of absolute values but also eliminates the effect of weights and measures on the results. The larger the absolute value is, the more obvious the effect. The I^2 test and Q test were used to evaluate the heterogeneity of each index. When $P \geq 0.1$ and $I^2 \leq 50\%$, there was homogeneity or low heterogeneity among the studies; in such cases, a fixed-effects model was used for analysis. When $P < 0.1$ and $I^2 > 50\%$, there was strong heterogeneity between studies; in such cases, a random-effects model was used for analysis. Subgroup analysis was conducted to calculate the influence of gross movement interventions on children's physical fitness based on the following factors: different physical fitness indicators, age, intervention duration, intervention frequency and single intervention duration.

3 Results

3.1 Literature search results

The results of the literature search and the study selection process are shown in Figure 1. All literature screenings were performed independently and in a double-blinded manner by 2 researchers (L.H. and S.W.) based on the inclusion and exclusion criteria. The search initially yielded 3,680 articles. First, the literature was classified, and duplicate studies were eliminated, leaving 3,148 studies. Second, after excluding 107 studies that were meta-analyses, reviews, or systematic reviews and 1,461 studies that were not related to the current subject, 1,580 studies remained. Then, 1,557 articles were excluded after full-text screening due to the intervention, trial design, or outcome variables not meeting our inclusion criteria. Finally, 23 studies were included in the meta-analysis. After screening, the two researchers compared the selected studies (Kappa≈0.65); therefore, the selected literature was considered reliable, and any disagreements were resolved by discussion with a third researcher (Q.L.P.).

3.2 Study characteristics

The main characteristics of the included studies are shown in Table 1. A total of 2,007 healthy children aged 3–10 years were included in the studies (1,037 in the experimental group and 970 in the control group). Nine studies included six outcome measures. The children's ages ranged from 3 to 10 years. The intervention duration ranged from 4 to 36 weeks. The intervention frequency ranged from 1 to 3 times per week. The duration of single sessions ranged from 30 to 60 min. Subgroup analysis was performed based on the following factors: physical quality factors (flexibility, explosive power, speed, upper-body strength, lower-body strength, balance); age (3–6 years old, 7–10 years old); duration of intervention (4–8, 10–12, 16–18, and 36 weeks); intervention frequency (1 time/week, 2 times/week, 3 times/week); and duration of a single session (30, 40, 45, and 60 min).

3.3 Risk of bias

The Cochrane risk of bias tool was used to evaluate the methodological quality of the included studies across six domains: selection bias, implementation bias, detection bias, loss of access bias and reporting bias (Figure 2). The kappa of the two researchers was approximately 0.62, so the literature quality evaluation was reliable. The risk of bias for each domain was categorized as low, unclear, or high, as shown in Figure 3.

3.4 Results of the meta-analysis

3.4.1 The influence of gross movement interventions on children's physical fitness

After analyzing the data from all included studies, we found that gross movement interventions improved physical fitness in children aged 3–10 years [SMD, 0.39 (95% CI, 0.22–0.57); $P < 0.05$], and there was significant heterogeneity (I^2 = 93%) (Figure 4). However, this effect did not differ according to various physical fitness factors, age, intervention duration, intervention frequency, or single-session duration. Therefore, a subgroup analysis was performed (Table 2).

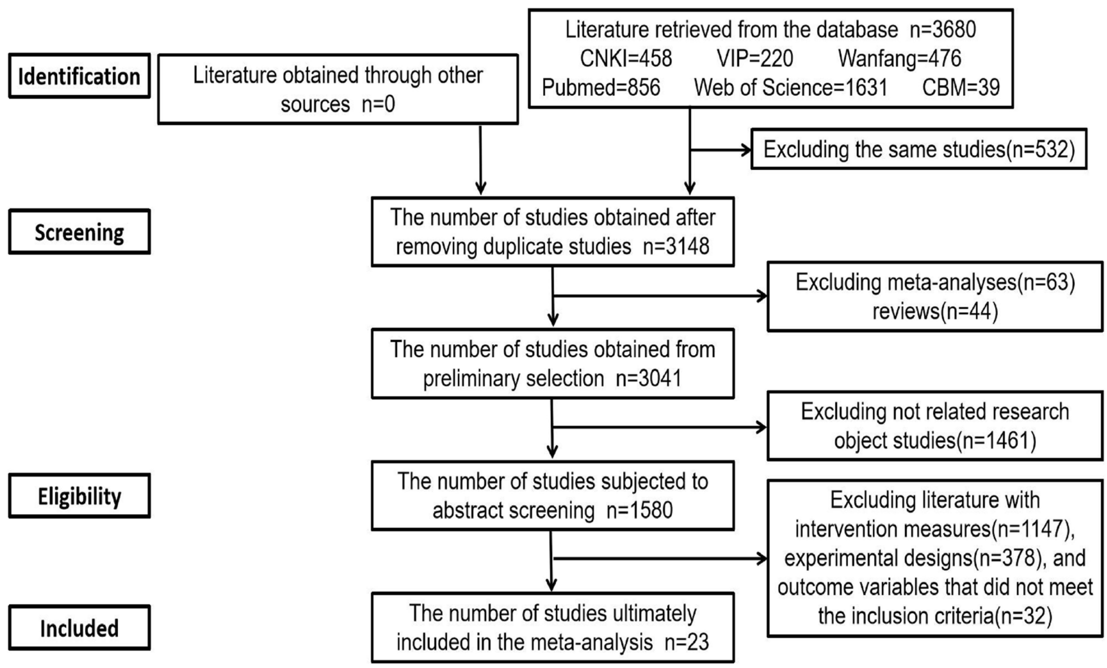

FIGURE 1
Flow chart of the literature retrieval and study selection process.

TABLE 1 Basic characteristics of the included studies.

References	Nationality	Male: Female	Age (year)	Sample size	Experimental group sample size	Control group sample size	Intervention measure	Intervention frequency (times/week)	Duration of intervention (weeks)	Duration of a single session (minutes/ session)	Primary outcome measure
Zou, 2016	China	42:42	10	84	42	42	Run, walk, pull, crawl, toss	3	16	40	①
Liu, 2014	China	53:34	5–6	87	45	42	Run, crawl, stand, roll, jump	3	12	40	①②③④⑤⑥
Wu, 2015	China	21:19	5–6	40	20	20	Run, jump, stand, pull	3	12	60	①②③④⑤⑥
Liu, 2016	China	/	9–10	60	30	30	Leg lifts, stretches, jumps, Throw the ball, run, crawl	3	12	/	①
Wright et al., 2015	United Kingdom	/	10	22	11	11	Run, crawl, squat, walk	2	4	/	①
Wei and Wei, 2016	China	12:8	9–10	20	10	10	Walk, squat, rotate, and lift your legs	2	8	/	①②
Liu, 2018	China	/	5	129	65	64	Run, jump, bounce the ball, catch the ball, slide forward, slide sideways, kick the ball, roll the ball	2	16	45	①②③④⑤⑥
Wang et al., 2018	China	54:0	9–10	40	20	20	Walk, run, stretch, dribble, shoot, pass	3	10	60	①②
Huang and Gao, 2018	China	/	9–10	72	36	36	Functional physical training (including gross movements)	3	16	/	①
Wang, 2020	China	/	9–10	54	28	26	Squat, high leg lift, jump, lunges, spins, major muscle stretches, ball lifts	3	12	/	①
Du et al., 2019	China	116:126	10	242	125	117	Running, jumping, ball games, roll, throw	1	18	/	①
Xia, 2020	China	/	4–5	61	21	18	Climb, stand, throw, walk, dribble, shoot, balance, jump	1/2	12	40	①②③

(Continued)

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TABLE 1 (Continued)

References	Nationality	Male: Female	Age (year)	Sample size	Experimental group sample size	Control group sample size	Intervention measure	Intervention frequency (times/week)	Duration of intervention (weeks)	Duration of a single session (minutes/ session)	Primary outcome measure
Zhao, 2020	China	31:29	5	60	30	30	Dribble, crawl, sidestep, throw, roll, set, toss, catch	3	16	40	①②③④⑤⑥
Jaksic et al., 2020	Mexico	72:60	4–7	132	66	66	Jumping, running, tumbling, throwing, ball games	2	36	60	①②
Gao, 2021	China	/	3–6	112	59	53	Catch the ball, dribble, kick the ball, throw the ball, jump, bounce the ball, step forward, step sideways	2	12	30–40	①②④⑤⑥
Xu, 2021	China	64:67	4–5	131	67	64	Functional play, stability skills, mobility skills, maneuverability skills, physical fitness activities	3	12	/	②③④⑤
Wang, 2021	China	/	4–5	104	54	50	Walk, climb, run, jump, throw, catch, kick, bounce, roll, dribble, stand	3	16	30	①②④⑤⑥
Zhou et al., 2021	China	/	4–5	173	94	79	Body motor function training methods (including gross movements)	3	18	40	①②③④⑤⑥
Chen, 2022	China	40:40	4–5	80	40	40	Toss, throw, bounce, kick, run, jump, slide, stretch, spin, shake, balance	3	10	45	①②③④⑤⑥
Ding, 2021	China	20:20	4–6	40	20	20	Run, dribble, catch, chase, toss	1	12	40	①②③④⑤⑥
Zheng, 2022	China	/	3–6	60	30	30	Run, jump, throw, bounce, kick, catch, roll	2	8	30	①②④⑤⑥
Zhou, 2022	China	60:60	4–5	120	60	60	Walk, run, jump, slide, crawl, balance, throw, catch, kick, bounce	3	12	40	①②③④⑤⑥
Fan, 2022	China	52:32	4–5	84	42	42	Functional sports games (including gross action)	3	12	45	①②③④⑤⑥

"①" means the sit-and-reach test, "②" means the standing long jump, "③" means the 10-meter shuttle run, "④" means the tennis ball throw for distance, "⑤" means two-foot continuous jumping, and "⑥" means the balance beam.

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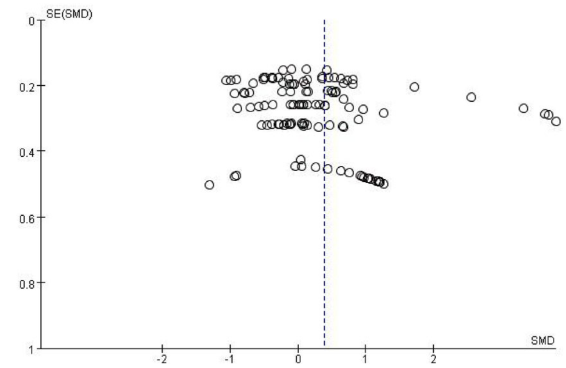

FIGURE 2
Funnel plot.

3.4.2 Subgroup analysis: effects of gross movement interventions on different physical fitness factors in children

The results varied when examining different physical fitness factors (Figure 5). Specifically, gross movement interventions significantly improved the following physical indicators: explosive power [WMD, 6.2 (95% CI, 4.28–8.11); $P < 0.05$], flexibility [WMD, 1.34 (95% CI, 0.25∼2.43); $P < 0.05$], balance [WMD, −1.23 (95% CI, 1.23∼0.42); $P < 0.05$], lower-body strength [WMD, 0.86 (95% CI, 1.41∼0.31); $P < 0.05$], upper-body strength [WMD, 0.79 (95% CI, 0.48∼1.11); $P < 0.05$], and speed [WMD, 0.72 (95% CI, 1.09∼0.35); $P < 0.05$]. However, there was significant heterogeneity in all six subgroups ($I^2 > 90.0\%$).

3.4.3 Subgroup analysis: effects of gross movement interventions on the physical fitness of children of different ages

The analysis results (Figure 6) showed that gross movement interventions significantly improved the physical fitness of children aged 7–10 years [SMD, 1.41 (95% CI, 0.11–0.46); $P < 0.05$], and there was significant heterogeneity ($I^2 = 97.0\%$). There was a small beneficial effect of gross movement interventions on the physical fitness of children aged 3–6 years [SMD, 0.18 (95% CI, 0.02–0.35); $P < 0.05$], and there was significant heterogeneity ($I^2 = 93.0\%$).

3.4.4 Subgroup analysis: the effect of different intervention durations on gross movement interventions on children's physical fitness

Subgroup analysis based on different intervention durations showed (Figure 7) that a gross movement intervention lasting 4–8 weeks had no significant effect on children's physical fitness [SMD, 0.03 (95% CI, −0.11 to 0.17); $P > 0.05$]. Gross movement interventions lasting 10–12 weeks had a small beneficial effect on children's physical fitness [SMD, 0.14 (95% CI, −0.13 to 0.41); $P < 0.05$]. Gross movement interventions lasting 16–18 weeks significantly improved children's physical fitness [SMD, 0.45 (95% CI, 0.02∼0.87); $P < 0.05$]. Gross movement interventions lasting 36 weeks also significantly improved children's physical fitness [SMD, 0.41 (95% CI, 0.16–0.65);$P < 0.05$].

3.4.5 Subgroup analysis: effects of gross movement interventions at different intervention frequencies on children's physical fitness

Subgroup analysis based on intervention frequencies showed (Figure 8) that one gross movement intervention per week significantly improved children's physical fitness [SMD, 1.06 (95% CI, 0.14–1.98); $P < 0.05$]. Two [SMD, 0.14 (95% CI, 0.01∼0.28); $P < 0.05$] and three [SMD, 0.13 (95% CI, −0.13∼0.39); $P < 0.05$] gross movement interventions per week had small beneficial effects on children's physical fitness. However, there was significant heterogeneity ($I^2 > 90.0\%$).

3.4.6 Subgroup analysis: the effect of different single-session durations of gross movement interventions on children's physical fitness

Subgroup analysis based on single-session durations (Figure 9) showed that 30-min gross movement interventions did not have a significant effect on children's physical fitness [SMD, −0.01 (95% CI, −0.11∼0.10); $P > 0.05$]. Furthermore, 40-min [SMD, −0.05 (95% CI, −0.45∼0.35); $P < 0.05$] and 45-min [SMD, −0.12 (95% CI, −0.38∼0.14); $P < 0.05$] gross movement interventions had detrimental effects on children's physical fitness. However, there was a high level of heterogeneity in these studies ($I^2 > 85\%$). Sixty-minute gross movement interventions effectively improved children's physical fitness [SMD, 0.47 (95% CI, 0.14–0.81); $P < 0.05$], and there was a moderate level of heterogeneity among these studies ($I^2 = 63.0\%$).

4 Discussion

This meta-analysis examined the influence of gross movement interventions on children's physical fitness and explored the optimal intervention parameters (i.e., physical fitness factors, age groups, intervention duration, intervention frequencies and single intervention duration). The results show that gross movement interventions can significantly improve children's physical fitness, with the strongest effects observed for explosive power. Additionally, we found that the effect of gross movement interventions was stronger for children aged 7–10 years, and the most effective intervention parameters included a frequency of once per week, a single-session duration of 60 min, and a total intervention duration of 16–18 weeks.

4.1 The influence of gross movement interventions on children's physical fitness

In general, this study revealed that gross movement interventions can improve the physical fitness of children aged 3–10 years, which is consistent with previous research results (Niederer et al., 2012; Fang et al., 2017). Notably, there is a significant positive correlation between gross movement performance and physical fitness among children (Angilley and Haggas, 2009; Zhou, 2020), especially in terms of flexibility, explosive power and speed (Schott et al., 2007; Haga, 2009). As

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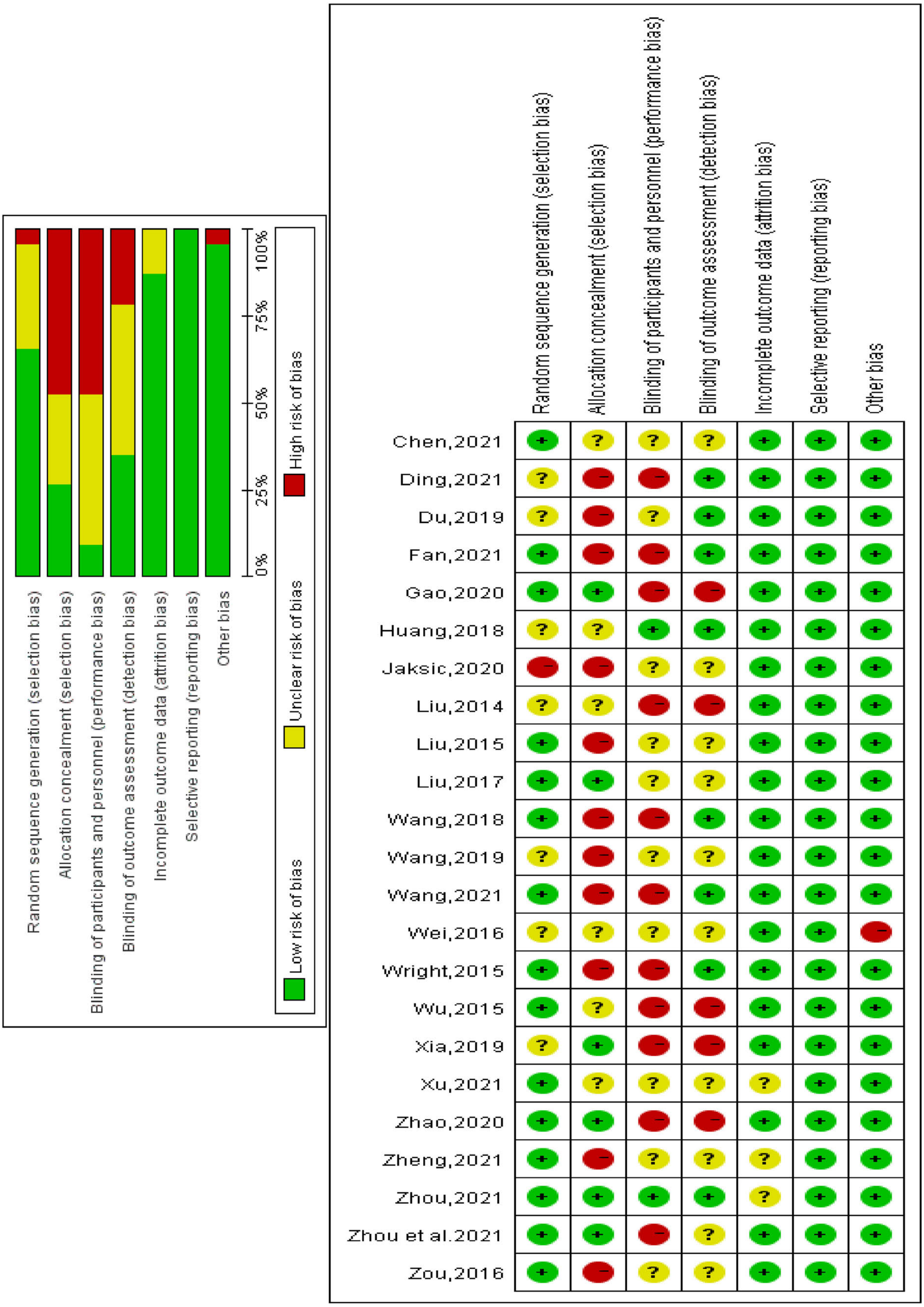

FIGURE 3
Results from the Cochrane risk of bias tool.

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Study or Subgroup	Control Mean	Control SD	Control Total	Experimental Mean	Experimental SD	Experimental Total	Weight	Std. Mean Difference IV, Random, 95% CI
Chen.H-Y(1),H(3) 2021	7.1	0.9	20	7.53	1.24	20	0.8%	-0.39 [-1.02, 0.24]
Chen.H-Y(1),H(3)2021	6.56	0.92	20	7.08	1	20	0.8%	-0.53 [-1.16, 0.10]
Chen.L-Y(1) ,L(3)2021	99.75	10.45	20	94	13.26	20	0.8%	0.47 [-0.16, 1.10]
Chen.L-Y(1),L(3)2021	92.16	11.42	20	91.45	11.38	20	0.8%	0.06 [-0.56, 0.68]
Chen.P-Y(1),P(3) 2021	6.69	0.61	20	6.87	0.69	20	0.8%	-0.27 [-0.89, 0.35]
Chen.P-Y(1),P(3)2021	7.34	0.64	20	7.56	0.86	20	0.8%	-0.28 [-0.91, 0.34]
Chen.S-Y(1),S(3) 2021	5.77	0.81	20	6.15	0.82	20	0.8%	-0.46 [-1.09, 0.17]
Chen.S-Y(1),S(3)2021	6.12	0.52	20	6.05	0.9	20	0.8%	0.09 [-0.53, 0.71]
Chen.W-Y(1),W(3) 2021	7.24	1.44	67	6.1	2.08	64	0.9%	0.64 [0.28, 0.99]
Chen.W-Y(1),W(3)2021	5.1	1.84	67	4.2	1.45	64	0.9%	0.54 [0.19, 0.89]
Chen.Z-Y(1),Z(3) 2021	9.88	2.87	20	10.1	1.7	20	0.8%	-0.09 [-0.71, 0.53]
Chen.Z-Y(1),Z(3)2021	10.29	2.42	20	10.73	2.76	20	0.8%	-0.17 [-0.79, 0.45]
Ding.H-Y(1),H(1) 2021	5.51	1.018	10	5.58	1.794	10	0.8%	-0.05 [-0.92, 0.83]
Ding.H-Y(1),H(1)2021	7.38	1.339	10	5.56	1.58	10	0.7%	1.19 [0.22, 2.16]
Ding.L-Y(1) ,L(1)2021	97.1	6.064	10	88.1	11.827	10	0.7%	0.92 [-0.01, 1.85]
Ding.L-Y(1),L(1)2021	81.5	8.885	10	74.9	7.923	10	0.7%	0.75 [-0.16, 1.67]
Ding.S-Y(1),S(1) 2021	5.9	0.733	10	5.26	0.55	10	0.7%	0.95 [0.01, 1.88]
Ding.S-Y(1),S(1)2021	6.95	0.669	10	6.05	0.766	10	0.7%	1.20 [0.23, 2.17]
Ding.W-Y(1) ,W(1)2021	9.3	2.21	67	7.9	0.97	64	0.9%	0.81 [0.45, 1.17]
Ding.W-Y(1),W(1)2021	7.6	1.01	67	6.3	0.31	64	0.9%	1.71 [1.31, 2.12]
Ding.Z-Y(1),Z(1) 2021	6.2	5.266	10	3.9	4.701	10	0.7%	0.44 [-0.45, 1.33]
Ding.Z-Y(1),Z(1)2021	5.5	4.836	10	1.4	3.026	10	0.7%	0.97 [0.03, 1.91]
Du et al.Z-Y(2),Z(1) 2019	9.2	0.48	61	3.9	0.83	55	0.7%	7.87 [6.78, 8.96]
Du et al.Z-Y(2),Z(1)2019	12.7	1.55	64	7.34	0.431	62	0.8%	4.65 [3.97, 5.33]
Fan.H-Y(1),H(3)2021	14.98	3.68	42	18.16	4.43	42	0.9%	-0.77 [-1.22, -0.33]
Fan.L-Y(1),L(3)2021	78.4	11.93	42	76.98	10.21	42	0.9%	0.13 [-0.30, 0.55]
Fan.P-Y(1),P(3)2021	9.4	0.78	42	9.49	0.84	42	0.9%	-0.11 [-0.54, 0.32]
Fan.S-Y(1),S(3)2021	8.63	1.31	42	8.95	1.34	42	0.9%	-0.24 [-0.67, 0.19]
Fan.W-Y(1),W(3)2021	7.37	2.42	62	6.67	1.3	62	0.9%	0.36 [0.00, 0.71]
Fan.Z-Y(1),Z(3)2021	6.92	4.49	42	4.91	3.26	42	0.9%	0.51 [0.07, 0.94]
Gao.H-Y(1),H(2)2021	5.09	4.98	59	4.78	1.48	53	0.9%	0.08 [-0.29, 0.45]
Gao.L-Y(1),L(2)2021	93.69	22.98	59	78	23	53	0.9%	0.68 [0.30, 1.06]
Gao.S-Y(1),S(2)2021	5.84	1.31	59	6.88	1.83	53	0.9%	-0.65 [-1.04, -0.27]
Gao.W-Y(1),W(2)2021	4.34	1.78	94	4.15	1.29	79	0.9%	0.12 [-0.18, 0.42]
Gao.Z-Y(1),Z(2)2021	7.44	4.29	59	8.4	4.45	53	0.9%	-0.22 [-0.59, 0.15]
Huang and Gao.Z-Y(2),Z(3)2018	10.47	3.07	36	8.41	3.02	36	0.9%	0.67 [0.19, 1.14]
Jaksic et al.Z-Y(1),Z(2)2020	37.3	7.82	66	34.36	8.38	66	0.9%	0.36 [0.02, 0.70]
Jaksic.L-Y(1),L(2)2020	121.98	20.44	66	112.98	19.06	66	0.9%	0.45 [0.11, 0.80]
Liu .H-Y(1),H(3)2014	5.02	0.83	45	5.76	0.74	42	0.9%	-0.93 [-1.37, -0.49]
Liu .L-Y(1),L(3)2014	104.4	9.92	45	99.11	11.12	42	0.9%	0.50 [0.07, 0.93]
Liu .P-Y(1),P(3)2014	6.65	0.48	45	7.03	0.57	42	0.9%	-0.72 [-1.15, -0.28]
Liu .S-Y(1),S(3)2014	5.5	0.82	45	6.1	0.67	42	0.9%	-0.79 [-1.23, -0.35]
Liu .W-Y(1),W(3)2014	6.23	1	20	5.66	0.68	20	0.8%	0.65 [0.02, 1.29]
Liu .Z-Y(1),Z(3)2014	9.88	1.26	45	9.05	1.68	42	0.9%	0.56 [0.13, 0.99]
Liu .Z-Y(2),Z(3)2015	11.8	2.32	30	12.01	3.17	30	0.9%	-0.07 [-0.58, 0.43]
Liu.L-Y(1),L(2)2017	121.61	15.88	62	111.4	12.09	62	0.9%	0.72 [0.36, 1.08]
Liu.P-Y(1),P(2)2017	6.09	0.48	62	6.32	0.41	62	0.9%	-0.51 [-0.87, -0.15]
Liu.S-Y(1),S(2)2017	4.85	0.73	62	5.16	0.92	62	0.9%	-0.37 [-0.73, -0.02]
Liu.W-Y(1),W(2)2017	5.67	0.68	20	5.18	0.75	20	0.8%	0.67 [0.03, 1.31]
Liu.Z-Y(1),Z(2)2017	11.29	5.09	62	11.88	3.46	62	0.9%	-0.13 [-0.49, 0.22]
Wang.H-Y(1),H(3)2021	24.58	15.2	54	22.86	15.02	50	0.9%	0.11 [-0.27, 0.50]
Wang.L-Y(1),L(3)2021	78.35	11.46	54	79.02	14.17	50	0.9%	-0.05 [-0.44, 0.33]
Wang.L-Y(2),L(3)2018	151	24	18	149	21	20	0.8%	0.09 [-0.55, 0.72]
Wang.P-Y(1),P(3)2021	8.45	0.97	54	8.5	0.88	50	0.9%	-0.05 [-0.44, 0.33]
Wang.S-Y(1),S(3)2021	8.49	3.55	54	8.93	3.57	50	0.9%	-0.12 [-0.51, 0.26]
Wang.Z-Y(1),Z(3)2021	5.2	5	54	5.61	5.35	50	0.9%	-0.08 [-0.46, 0.31]
Wang.Z-Y(2),Z(3)2018	10.3	5.6	18	8.5	6.3	20	0.8%	0.29 [-0.35, 0.94]
Wang.Z-Y(2),Z(3)2019	13.71	3.4	24	10.39	3.94	24	0.8%	0.89 [0.29, 1.48]
Wei.L-Y(2),L(2)2016	155.7	14.04	10	152	12.7	10	0.7%	0.26 [-0.62, 1.15]
Wei.Z-Y(2),Z(2)2016	6.8	4.75	10	4	3.71	10	0.7%	0.63 [-0.27, 1.53]
Wright. Z-Y(2),Z(2)2015	13	22	11	12	18	11	0.8%	0.05 [-0.79, 0.88]
Wu.L-Y(1),L(3) 2015	110.5	5.15	10	106.2	2.31	10	0.7%	1.03 [0.09, 1.98]
Wu.L-Y(1),L(3)2015	108.9	4.45	10	104.5	1.67	10	0.7%	1.25 [0.28, 2.23]
Wu.S-Y(1),S(3) 2015	4.9	1.12	10	5.7	0.45	10	0.7%	-0.90 [-1.83, 0.03]
Wu.S-Y(1),S(3)2015	5.2	1.71	10	6.4	0.34	10	0.7%	-0.93 [-1.87, 0.00]
Wu.W-Y(1) ,W(3)2015	7.2	1.01	10	6.3	0.33	10	0.7%	1.15 [0.19, 2.11]
Wu.W-Y(1),W(3)2015	6.7	0.14	10	5.1	2.02	10	0.7%	1.07 [0.12, 2.02]
Wu.Z-Y(1),Z(3) 2015	11.4	3.28	10	8.3	1.16	10	0.7%	1.21 [0.24, 2.18]
Wu.Z-Y(1),Z(3)2015	14.7	4.03	10	11.2	2.16	10	0.7%	1.04 [0.09, 1.98]
Xia.L-Y(1),L(1)2019	92.29	12.02	21	95.11	14.36	18	0.8%	-0.21 [-0.84, 0.42]
Xia.L-Y(1),L(2)2019	93.27	16.96	22	95.11	14.36	18	0.8%	-0.11 [-0.74, 0.51]
Xia.P-Y(1),P(1)2019	8.38	1.36	21	8.73	2.03	18	0.8%	-0.20 [-0.83, 0.43]
Xia.P-Y(1),P(2)2019	8.54	1.06	22	8.73	2.03	18	0.8%	-0.12 [-0.74, 0.50]
Xia.Z-Y(1),Z(1) 2019	7.28	3.35	21	6.82	3.37	18	0.8%	0.13 [-0.50, 0.76]
Xia.Z-Y(1),Z(1)2019	7.02	2.52	22	6.82	3.37	18	0.8%	0.07 [-0.56, 0.69]
Xu .P-Y(1), P(3) 2021	7.5	1.34	67	7.9	0.56	64	0.9%	-0.38 [-0.73, -0.04]
Xu. L-Y(1),L(3) 2021	82	2.49	67	75	1.6	64	0.9%	3.31 [2.78, 3.84]
Xu.L-Y(1), L(3) 2021	87	2.56	67	79	1.63	64	0.8%	3.69 [3.12, 4.26]
Xu.L-Y(1),L(3) 2021	114.2	1.74	67	108.7	2.51	64	0.9%	2.54 [2.08, 3.01]
Xu.L-Y(1),L(3)2021	106.4	2.6	67	98	1.94	64	0.8%	3.63 [3.07, 4.19]
Xu.P-Y(1), P(3) 2021	7.1	0.89	67	7.3	0.36	64	0.9%	-0.29 [-0.63, 0.05]
Xu.P-Y(1),P(3) 2021	6	0.76	67	6.7	1.92	64	0.9%	-0.48 [-0.83, -0.13]
Xu.P-Y(1),P(3)2021	6.2	1.03	67	7	0.47	64	0.9%	-0.99 [-1.35, -0.62]
Xu.S-Y (1),S(3)2021	6.3	2.32	67	7	0.94	64	0.9%	-0.39 [-0.74, -0.04]
Xu.S-Y(1), S(3) 2021	6.5	1.12	67	7.8	1.71	64	0.9%	-0.90 [-1.26, -0.54]
Xu.S-Y(1),S(3) 2021	5.2	2.12	67	6.1	1.32	64	0.9%	-0.50 [-0.85, -0.16]
Xu.S-Y(1),S(3)2021	5.1	1.12	67	6.2	0.94	64	0.9%	-1.06 [-1.42, -0.69]
Xu.W-Y(1), W(3) 2021	5	1.01	30	4	1.06	30	0.9%	0.95 [0.42, 1.49]
Xu.W-Y(1), W(3)2021	7.41	1.97	45	6.5	2.09	42	0.9%	0.44 [0.02, 0.87]
Xu.W-Y(1),W(3) 2021	5.85	1.216	10	4.26	1.372	10	0.7%	1.17 [0.21, 2.14]
Xu.W-Y(1),W(3)2021	4.6	0.748	10	4.55	0.972	10	0.8%	0.06 [-0.82, 0.93]
Zhao.H-Y(1),H(3)2020	6.3	1.88	30	7.9	2.56	30	0.9%	-0.70 [-1.23, -0.18]
Zhao.L-Y(1),L(3)2020	97	10.81	30	85	7.75	30	0.8%	1.26 [0.70, 1.82]
Zhao.P-Y(1),P(3)2020	6.9	0.57	30	7.5	0.74	30	0.9%	-0.90 [-1.43, -0.36]
Zhao.W-Y(1),W(3)2020	3.8	0.59	30	3.79	0.61	30	0.9%	0.02 [-0.49, 0.52]
Zhao.Z-Y(1),Z(3)2020	12.3	4.96	30	8.9	3.81	30	0.9%	0.76 [0.23, 1.28]
Zheng. W-Y(1),W(2)2021	5.96	1.08	30	5.89	1.19	30	0.9%	0.06 [-0.45, 0.57]
Zheng. Z-Y(1),Z(2) 2021	10.89	2.06	30	11.79	1.47	30	0.9%	-0.50 [-1.01, 0.02]
Zheng.H-Y(1) ,H(2)2021	13.04	3.59	30	12.66	4.93	30	0.9%	0.09 [-0.42, 0.59]
Zheng.H-Y(1),H(2) 2021	8.63	1.19	30	8.16	1.71	30	0.9%	0.31 [-0.19, 0.82]
Zheng.H-Y(1),H(2)2021	5.1	1.68	30	5.88	0.92	30	0.9%	-0.57 [-1.09, -0.05]
Zheng.L-Y(1) ,L(2)2021	70.73	9.57	30	66.99	8.98	30	0.9%	0.40 [-0.11, 0.91]
Zheng.L-Y(1),L(2) 2021	89.08	8.7	30	89.75	9.79	30	0.9%	-0.07 [-0.58, 0.43]
Zheng.L-Y(1),L(2)2021	112.75	12.78	30	114	10.52	30	0.9%	-0.11 [-0.61, 0.40]
Zheng.S-Y(1), S(2)2021	9.18	0.76	30	9.04	1.24	30	0.9%	0.13 [-0.37, 0.64]
Zheng.S-Y(1),S(2) 2021	4.52	0.55	30	4.27	0.67	30	0.9%	0.40 [-0.11, 0.91]
Zheng.S-Y(1),S(2) 2021	5.47	1.35	30	5.44	1.17	30	0.9%	0.02 [-0.48, 0.53]
Zheng.W-Y(1), W(2)2021	7.24	0.95	30	7.05	0.41	30	0.9%	0.26 [-0.25, 0.76]
Zheng.W-Y(1),W(2)2021	4.97	0.332	60	3.37	0.49	60	0.8%	3.80 [3.19, 4.40]
Zheng.Z-Y(1),Z(2) 2021	10.96	2.2	30	10.73	3.49	30	0.9%	0.08 [-0.43, 0.58]
Zheng.Z-Y(1),Z(2)2021	10.8	3.85	30	12.15	3.34	30	0.9%	-0.37 [-0.88, 0.14]
Zhou .L-Y(1),L(3)2021	99.83	4.013	60	74.3	6.171	60	0.8%	4.87 [4.15, 5.60]
Zhou .W-Y(1),W(3)2021	3.91	1.13	42	3.74	1.14	42	0.9%	0.15 [-0.28, 0.58]
Zhou .Z-Y(1),Z(3)2021	5.81	1.872	60	5.54	1.958	60	0.9%	0.14 [-0.22, 0.50]
Zhou.H-Y(1),H(3)2021	7.43	3.37	94	7.82	4.35	79	0.9%	-0.10 [-0.40, 0.20]
Zhou.L-Y(1),L(3)2021	102.26	13.69	94	96.41	14.24	79	0.9%	0.42 [0.12, 0.72]
Zhou.W-Y(1),W(3)2021	6.49	2.47	59	4.75	1.65	53	0.9%	0.81 [0.43, 1.20]
Zhou.Z-Y(1),Z(3)2021	11.17	4.91	94	12.28	5.09	79	0.9%	-0.22 [-0.52, 0.08]
Zou.Z-Y(2),Z(3)2016	9.37	3.02	42	7.71	3.06	42	0.9%	0.54 [0.11, 0.98]
Total (95% CI)			**4630**			**4429**	**100.0%**	**0.39 [0.22, 0.57]**

Heterogeneity: $Tau^2 = 0.84$; $Chi^2 = 1797.97$, $df = 118$ ($P < 0.00001$); $I^2 = 93\%$
Test for overall effect: $Z = 4.43$ ($P < 0.00001$)

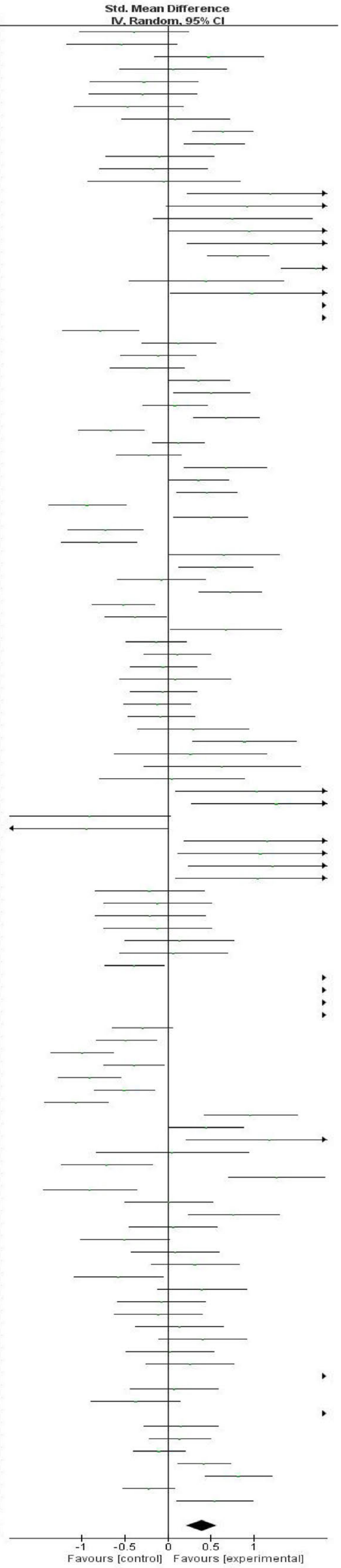

FIGURE 4
The effects of gross movement interventions on physical fitness.

TABLE 2 Summary of subgroup analysis results.

Grouping standard	Groups	Effect size
Physical fitness factors	Explosive power	6.20
	Flexibility	1.34
	Balance	−1.23
	Lower-body strength	−0.86
	Upper-body strength	0.79
	Speed	−0.72
Age range	3–6 years old	0.18
	7–10 years old	1.41
Intervention duration	4–8 weeks	0.03
	10–12 weeks	0.14
	16–18 weeks	0.45
	36 weeks	0.41
Intervention frequency	One time/week	1.06
	Two times/week	0.14
	Three times/week	0.13
Single-session duration	30 min	−0.01
	40 min	−0.05
	45 min	−0.12
	60 min	0.47

they age, children with high levels of gross movement ability exhibit greater physical fitness (Hands, 2008). This relationship suggests that gross movement interventions in early childhood will have a sustained positive impact on physical fitness, probably because children with strong gross motor ability will complete more complex physical activities, which may play a key role in the development of physical fitness.

Additionally, we found that gross movement interventions had the most significant effect on the explosive power of children aged 3–10 years, and no other studies reported such a significant effect (Hands, 2008; Wu et al., 2021; Chen and Gu, 2022). There are many reasons for thisresult. From the perspective of the experimental subjects included in the study, most of the subjects in this study were Chinese children, and explosive power changed significantly after the gross movement intervention, which may be related to genetic factors (Brandes, 2012). From the perspective of test methods, the experimental subjects included in the study mainly used standing long jumps to test children's explosive power. A standing long jump is an important training method for improving explosive power, with medium and low intensity and low technical requirements (Dong et al., 2022). Furthermore, it is easier for children to master this skill. However, the excitability of the central nervous system is an important factor affecting explosive power (Wu et al., 2018; Chen et al., 2021), and running and jumping during gross movement interventions effectively improve the excitability of children's nervous system (Loukia and Dimitris, 2022), thus recruiting more muscle fibers to participate in activities in the short term and improving the quality of explosive power. Therefore, among physical factors, gross movement interventions have the strongest effect on explosive power among children aged 3–10 years. However, it is necessary to consider the influence of genetic factors and testing methods.

4.2 The influence of gross movement interventions on the physical fitness of children of different ages

The effect of gross movement interventions on the physical fitness of children aged 7–10 years was greater than that on the physical fitness of children aged 3–6 years, which is consistent with some previous research results (Latorre Román et al., 2017; Li et al., 2019; Xin et al., 2019). The development and completion of gross movement is influenced by the integration of complex factors such as physiology, psychology, environment and task (Robinson et al., 2015; Li et al., 2019). This may reflect that as children age, they experience development in terms of their bones, muscles, cognitive abilities and nervous system, and they show increased adaptability to complex motor skills. Therefore, the effect of gross movement interventions on physical fitness is stronger among 7- to 10-year-old children. Previous studies have confirmed that children usually consolidate their learning and engage in continuous practice after the age of 6 (Venetsanou and Kambas, 2010; Chow and Louie, 2013), and mastery of gross motor skills begins to increase (Haywood and Gallahue, 2014). With increasing age, the mastery of gross motor skills significantly increases (Zhou, 2020). However, there are also studies showing that some physical fitness factors decrease with age (Gulías-González et al., 2014; Lopes et al., 2017; Godoy-Cumillaf et al., 2020), possibly related to the number of training sessions, the length of training sessions or other factors (Lopes et al., 2013).

4.3 Effects of different intervention durations on the physical fitness of children aged 3–10 years

When the intervention frequency was 10–12 weeks, the improvement effect of gross movement interventions on children's physical fitness reached a significant level. The effect peaked when the intervention lasted 16–18 weeks. After 18 weeks, the effect of the intervention decreased slightly. This finding is consistent with the findings of a study that confirmed the positive impact of medium- to long-term gross movement interventions on physical fitness in children (Jaksic et al., 2020). This may be related to the improvement of motor skill levels under medium- and long-term interventions; in particular, after approximately 10 weeks of physical activity intervention, children's motor skill levels are significantly improved, and the intervention benefits on children's physical fitness persist (Bellows et al., 2013; Roth et al., 2015). It is also possible that improvements in children's cognitive function have a positive impact on physical fitness. Gross movement is positively correlated with cognitive function (Thelen, 1995). A study of the effects of sports interventions on children's cognitive function showed that after approximately 10 weeks of physical activity intervention, children's cognitive function improved, and physical health benefits increased (Fisher et al., 2011). Another study from the perspective of child psychology and modern medicine supported the positive impact of children's motor development on cognitive function (Wu et al., 2023). It can be inferred that improving children's cognitive function through gross movement interventions can effectively enhance their physical fitness.

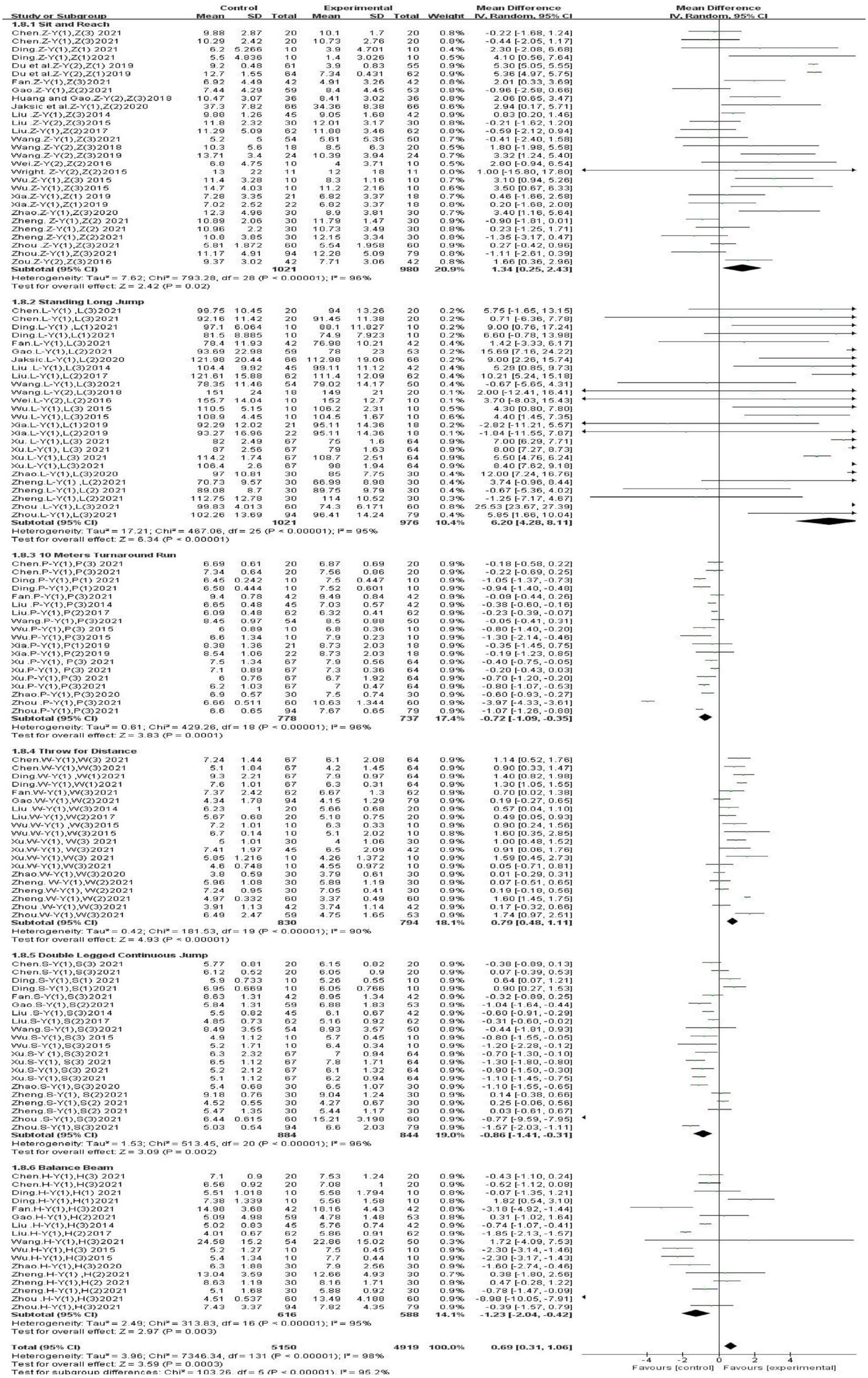

FIGURE 5
Different physical fitness factors.

Study or Subgroup	Control Mean	Control SD	Control Total	Experimental Mean	Experimental SD	Experimental Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.3.1 3-6Years								
Chen.H-Y(1),H(3) 2021	7.1	0.9	20	7.53	1.24	20	0.8%	-0.39 [-1.02, 0.24]
Chen.H-Y(1),H(3)2021	6.56	0.92	20	7.08	1	20	0.8%	-0.53 [-1.16, 0.10]
Chen.L-Y(1) ,L(3)2021	99.75	10.45	20	94	13.26	20	0.8%	0.47 [-0.16, 1.10]
Chen.L-Y(1),L(3)2021	92.16	11.42	20	91.45	11.38	20	0.8%	0.06 [-0.56, 0.68]
Chen.P-Y(1),P(3) 2021	6.69	0.61	20	6.87	0.69	20	0.8%	-0.27 [-0.89, 0.35]
Chen.P-Y(1),P(3)2021	7.34	0.64	20	7.56	0.86	20	0.8%	-0.28 [-0.91, 0.34]
Chen.S-Y(1),S(3) 2021	5.77	0.81	20	6.15	0.82	20	0.8%	-0.46 [-1.09, 0.17]
Chen.S-Y(1),S(3)2021	6.12	0.52	20	6.05	0.9	20	0.8%	0.09 [-0.53, 0.71]
Chen.W-Y(1),W(3) 2021	6.23	1	20	5.66	0.68	20	0.8%	0.65 [0.02, 1.29]
Chen.W-Y(1),W(3)2021	5.67	0.68	20	5.18	0.75	20	0.8%	0.67 [0.03, 1.31]
Chen.Z-Y(1),Z(3) 2021	9.88	2.87	20	10.1	1.7	20	0.8%	-0.09 [-0.71, 0.53]
Chen.Z-Y(1),Z(3)2021	10.29	2.42	20	10.73	2.76	20	0.8%	-0.17 [-0.79, 0.45]
Ding.H-Y(1),H(1) 2021	5.51	1.018	10	5.58	1.794	10	0.7%	-0.05 [-0.92, 0.83]
Ding.H-Y(1),H(1)2021	7.38	1.339	10	5.56	1.58	10	0.7%	1.19 [0.22, 2.16]
Ding.L-Y(1) ,L(1)2021	97.1	6.064	10	88.1	11.827	10	0.7%	0.92 [-0.01, 1.85]
Ding.L-Y(1),L(1)2021	81.5	8.885	10	74.9	7.923	10	0.7%	0.75 [-0.16, 1.67]
Ding.P-Y(1),P(1)2021	6.58	0.444	10	7.52	0.601	10	0.7%	-1.70 [-2.76, -0.65]
Ding.S-Y(1),S(1) 2021	5.9	0.733	10	5.26	0.55	10	0.7%	0.95 [0.01, 1.88]
Ding.S-Y(1),S(1)2021	6.95	0.669	10	6.05	0.766	10	0.7%	1.20 [0.23, 2.17]
Ding.W-Y(1) ,W(1)2021	5.85	1.216	10	4.26	1.372	10	0.7%	1.17 [0.21, 2.14]
Ding.W-Y(1),W(1)2021	4.6	0.748	10	4.55	0.972	10	0.7%	0.06 [-0.82, 0.93]
Ding.Z-Y(1),Z(1) 2021	6.2	5.266	10	3.9	4.701	10	0.7%	0.44 [-0.45, 1.33]
Ding.Z-Y(1),Z(1)2021	5.5	4.836	10	1.4	3.026	10	0.7%	0.97 [0.03, 1.91]
Fan.H-Y(1),H(3)2021	14.98	3.68	42	18.16	4.43	42	0.8%	-0.77 [-1.22, -0.33]
Fan.L-Y(1),L(3)2021	78.4	11.93	42	76.98	10.21	42	0.8%	0.13 [-0.30, 0.55]
Fan.P-Y(1),P(3)2021	9.4	0.78	42	9.49	0.84	42	0.8%	-0.11 [-0.54, 0.32]
Fan.S-Y(1),S(3)2021	8.63	1.31	42	8.95	1.34	42	0.8%	-0.24 [-0.67, 0.19]
Fan.W-Y(1),W(3)2021	3.91	1.13	42	3.74	1.14	42	0.8%	0.15 [-0.28, 0.58]
Fan.Z-Y(1),Z(3)2021	6.92	4.49	42	4.91	3.26	42	0.8%	0.51 [0.07, 0.94]
Gao.H-Y(1),H(2)2021	5.09	4.98	59	4.78	1.48	53	0.8%	0.08 [-0.29, 0.45]
Gao.L-Y(1),L(2)2021	93.69	22.98	59	78	23	53	0.8%	0.68 [0.30, 1.06]
Gao.S-Y(1),S(2)2021	5.84	1.31	59	6.88	1.83	53	0.8%	-0.65 [-1.04, -0.27]
Gao.W-Y(1),W(2)2021	6.49	2.47	59	4.75	1.65	53	0.8%	0.81 [0.43, 1.20]
Gao.Z-Y(1),Z(2)2021	7.44	4.29	59	8.4	4.45	53	0.8%	-0.22 [-0.59, 0.15]
Jaksic et al.Z-Y(1),Z(2)2020	37.3	7.82	66	34.36	8.38	66	0.8%	0.36 [0.02, 0.70]
Jaksic.L-Y(1),L(2)2020	121.98	20.44	66	112.98	19.06	66	0.8%	0.45 [0.11, 0.80]
Liu .H-Y(1),H(3)2014	5.02	0.83	45	5.76	0.74	42	0.8%	-0.93 [-1.37, -0.49]
Liu .L-Y(1),L(3)2014	104.4	9.92	45	99.11	11.12	42	0.8%	0.50 [0.07, 0.93]
Liu .P-Y(1),P(3)2014	6.65	0.48	45	7.03	0.57	42	0.8%	-0.72 [-1.15, -0.28]
Liu .S-Y(1),S(3)2014	5.5	0.82	45	6.1	0.67	42	0.8%	-0.79 [-1.23, -0.35]
Liu .W-Y(1),W(3)2014	7.41	1.97	45	6.5	2.09	42	0.8%	0.44 [0.02, 0.87]
Liu .Z-Y(1),Z(3)2014	9.88	1.26	45	9.05	1.68	42	0.8%	0.56 [0.13, 0.99]
Liu.L-Y(1),L(2)2017	121.61	15.88	62	111.4	12.09	62	0.8%	0.72 [0.36, 1.08]
Liu.P-Y(1),P(2)2017	6.09	0.48	62	6.32	0.41	62	0.8%	-0.51 [-0.87, -0.15]
Liu.S-Y(1),S(2)2017	4.85	0.73	62	5.16	0.92	62	0.8%	-0.37 [-0.73, -0.02]
Liu.W-Y(1),W(2)2017	7.37	2.42	62	6.67	1.3	62	0.8%	0.36 [0.00, 0.71]
Liu.Z-Y(1),Z(2)2017	11.29	5.09	62	11.88	3.46	62	0.8%	-0.13 [-0.49, 0.22]
Wang.H-Y(1),H(3)2021	24.58	15.2	54	22.86	15.02	50	0.8%	0.11 [-0.27, 0.50]
Wang.L-Y(1),L(3)2021	78.35	11.46	54	79.02	14.17	50	0.8%	-0.05 [-0.44, 0.33]
Wang.P-Y(1),P(3)2021	8.45	0.97	54	8.5	0.88	50	0.8%	-0.05 [-0.44, 0.33]
Wang.S-Y(1),S(3)2021	8.49	3.55	54	8.93	3.57	50	0.8%	-0.12 [-0.51, 0.26]
Wang.Z-Y(1),Z(3)2021	5.2	5	54	5.61	5.35	50	0.8%	-0.08 [-0.46, 0.31]
Wu .P-Y(1),P(3) 2015	6.6	1.34	10	7.9	0.23	10	0.7%	-1.30 [-2.28, -0.31]
Wu.H-Y(1),H(3) 2015	5.2	1.27	10	7.5	0.45	10	0.6%	-2.31 [-3.50, -1.13]
Wu.H-Y(1),H(3)2015	5.4	1.34	10	7.7	0.44	10	0.6%	-2.21 [-3.37, -1.05]
Wu.L-Y(1),L(3) 2015	110.5	5.15	10	106.2	2.31	10	0.7%	1.03 [0.09, 1.98]
Wu.L-Y(1),L(3)2015	108.9	4.45	10	104.5	1.67	10	0.7%	1.25 [0.28, 2.23]
Wu.P-Y(1),P(3) 2015	6	0.89	10	6.8	0.36	10	0.7%	-1.13 [-2.09, -0.17]
Wu.S-Y(1),S(3) 2015	4.9	1.12	10	5.7	0.45	10	0.7%	-0.90 [-1.83, 0.03]
Wu.S-Y(1),S(3)2015	5.2	1.71	10	6.4	0.34	10	0.7%	-0.93 [-1.87, 0.00]
Wu.W-Y(1) ,W(3)2015	7.2	1.01	10	6.3	0.33	10	0.7%	1.15 [0.19, 2.11]
Wu.W-Y(1),W(3)2015	6.7	0.14	10	5.1	2.02	10	0.7%	1.07 [0.12, 2.02]
Wu.Z-Y(1),Z(3) 2015	11.4	3.28	10	8.3	1.16	10	0.7%	1.21 [0.24, 2.18]
Wu.Z-Y(1),Z(3)2015	14.7	4.03	10	11.2	2.16	10	0.7%	1.04 [0.09, 1.98]
Xia.L-Y(1),L(1)2019	92.29	12.02	21	95.11	14.36	18	0.8%	-0.21 [-0.84, 0.42]
Xia.L-Y(1),L(2)2019	93.27	16.96	22	95.11	14.36	18	0.8%	-0.11 [-0.74, 0.51]
Xia.P-Y(1),P(1)2019	8.38	1.36	21	8.73	2.03	18	0.8%	-0.20 [-0.83, 0.43]
Xia.P-Y(1),P(2)2019	8.54	1.06	22	8.73	2.03	18	0.8%	-0.12 [-0.74, 0.50]
Xia.Z-Y(1),Z(1) 2019	7.28	3.35	21	6.82	3.37	18	0.8%	0.13 [-0.50, 0.76]
Xia.Z-Y(1),Z(1)2019	7.02	2.52	22	6.82	3.37	18	0.8%	0.07 [-0.56, 0.69]
Xu .P-Y(1), P(3) 2021	7.5	1.34	67	7.9	0.56	64	0.8%	-0.38 [-0.73, -0.04]
Xu. L-Y(1),L(3) 2021	82	2.49	67	75	1.6	64	0.8%	3.31 [2.78, 3.84]
Xu.L-Y(1), L(3) 2021	87	2.56	67	79	1.63	64	0.8%	3.69 [3.12, 4.26]
Xu.L-Y(1),L(3) 2021	114.2	1.74	67	108.7	2.51	64	0.8%	2.54 [2.08, 3.01]
Xu.L-Y(1),L(3)2021	106.4	2.6	67	98	1.94	64	0.8%	3.63 [3.07, 4.19]
Xu.P-Y(1), P(3) 2021	7.1	0.89	67	7.3	0.36	64	0.8%	-0.29 [-0.63, 0.05]
Xu.P-Y(1),P(3) 2021	6	0.76	67	6.7	1.92	64	0.8%	-0.48 [-0.83, -0.13]
Xu.P-Y(1),P(3)2021	6.2	1.03	67	7	0.47	64	0.8%	-0.99 [-1.35, -0.62]
Xu.S-Y (1),S(3)2021	6.3	2.32	67	7	0.94	64	0.8%	-0.39 [-0.74, -0.04]
Xu.S-Y(1), S(3) 2021	6.5	1.12	67	7.8	1.71	64	0.8%	-0.90 [-1.26, -0.54]
Xu.S-Y(1),S(3) 2021	5.2	2.12	67	6.1	1.32	64	0.8%	-0.50 [-0.85, -0.16]
Xu.S-Y(1),S(3)2021	5.1	1.12	67	6.2	0.94	64	0.8%	-1.06 [-1.42, -0.69]
Xu.W-Y(1), W(3) 2021	7.24	1.44	67	6.1	2.08	64	0.8%	0.64 [0.28, 0.99]
Xu.W-Y(1), W(3)2021	5.1	1.84	67	4.2	1.45	64	0.8%	0.54 [0.19, 0.89]
Xu.W-Y(1),W(3) 2021	9.3	2.21	67	7.9	0.97	64	0.8%	0.81 [0.45, 1.17]
Xu.W-Y(1),W(3)2021	7.6	1.01	67	6.3	0.31	64	0.8%	1.71 [1.31, 2.12]
Zhao.H-Y(1),H(3)2020	6.3	1.88	30	7.9	2.56	30	0.8%	-0.70 [-1.23, -0.18]
Zhao.L-Y(1),L(3)2020	97	10.81	30	85	7.75	30	0.8%	1.26 [0.70, 1.82]
Zhao.P-Y(1),P(3)2020	6.9	0.57	30	7.5	0.74	30	0.8%	-0.90 [-1.43, -0.36]
Zhao.S-Y(1),S(3)2020	5.4	0.68	30	6.5	1.07	30	0.8%	-1.21 [-1.76, -0.66]
Zhao.W-Y(1),W(3)2020	5	1.01	30	4	1.06	30	0.8%	0.95 [0.42, 1.49]
Zhao.Z-Y(1),Z(3)2020	12.3	4.96	30	8.9	3.81	30	0.8%	0.76 [0.23, 1.28]
Zheng. W-Y(1),W(2)2021	3.8	0.59	30	3.79	0.61	30	0.8%	0.02 [-0.49, 0.52]
Zheng. Z-Y(1),Z(2) 2021	10.89	2.06	30	11.79	1.47	30	0.8%	-0.50 [-1.01, 0.02]
Zheng.H-Y(1) ,H(2)2021	13.04	3.59	30	12.66	4.93	30	0.8%	0.09 [-0.42, 0.59]
Zheng.H-Y(1),H(2) 2021	8.63	1.19	30	8.16	1.71	30	0.8%	0.31 [-0.19, 0.82]
Zheng.H-Y(1),H(2)2021	5.1	1.68	30	5.88	0.92	30	0.8%	-0.57 [-1.09, -0.05]
Zheng.L-Y(1) ,L(2)2021	70.73	9.57	30	66.99	8.98	30	0.8%	0.40 [-0.11, 0.91]
Zheng.L-Y(1),L(2) 2021	89.08	8.7	30	89.75	9.79	30	0.8%	-0.07 [-0.58, 0.43]
Zheng.L-Y(1),L(2)2021	112.75	12.78	30	114	10.52	30	0.8%	-0.11 [-0.61, 0.40]
Zheng.S-Y(1), S(2)2021	9.18	0.76	30	9.04	1.24	30	0.8%	0.13 [-0.37, 0.64]
Zheng.S-Y(1),S(2) 2021	5.47	1.35	30	5.44	1.17	30	0.8%	0.02 [-0.48, 0.53]
Zheng.S-Y(1),S(2)2021	4.52	0.55	30	4.27	0.67	30	0.8%	0.40 [-0.11, 0.91]
Zheng.W-Y(1), W(2)2021	5.96	1.08	30	5.89	1.19	30	0.8%	0.06 [-0.45, 0.57]
Zheng.W-Y(1),W(2)2021	7.24	0.95	30	7.05	0.41	30	0.8%	0.26 [-0.25, 0.76]
Zheng.Z-Y(1),Z(2) 2021	10.96	2.2	30	10.73	3.49	30	0.8%	0.08 [-0.43, 0.58]
Zheng.Z-Y(1),Z(2)2021	10.8	3.85	30	12.15	3.34	30	0.8%	-0.37 [-0.88, 0.14]
Zhou .L-Y(1),L(3)2021	99.83	4.013	60	74.3	6.171	60	0.8%	4.87 [4.15, 5.60]
Zhou .W-Y(1),W(3)2021	4.97	0.332	60	3.37	0.49	60	0.8%	3.80 [3.19, 4.40]
Zhou .Z-Y(1),Z(3)2021	5.81	1.872	60	5.54	1.958	60	0.8%	0.14 [-0.22, 0.50]
Zhou.H-Y(1),H(3)2021	7.43	3.37	94	7.82	4.35	79	0.8%	-0.10 [-0.40, 0.20]
Zhou.L-Y(1),L(3)2021	102.26	13.69	94	96.41	14.24	79	0.8%	0.42 [0.12, 0.72]
Zhou.P-Y(1),P(3)2021	6.6	0.65	94	7.67	0.65	79	0.8%	-1.64 [-1.99, -1.29]
Zhou.S-Y(1),S(3)2021	5.03	0.54	94	6.6	2.03	79	0.8%	-1.09 [-1.42, -0.77]
Zhou.W-Y(1),W(3)2021	4.34	1.78	94	4.15	1.29	79	0.8%	0.12 [-0.18, 0.42]
Zhou.Z-Y(1),Z(3)2021	11.17	4.91	94	12.28	5.09	79	0.8%	-0.22 [-0.52, 0.08]
Subtotal (95% CI)			**4574**			**4347**	**91.6%**	**0.18 [0.02, 0.35]**
Heterogeneity: Tau² = 0.78; Chi² = 1660.36, df = 115 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 2.14 (P = 0.03)								
2.3.2 7-10Years								
Du et al.Z-Y(2),Z(1) 2019	9.2	0.48	61	3.9	0.83	55	0.6%	7.87 [6.78, 8.96]
Du et al.Z-Y(2),Z(1)2019	12.7	1.55	64	7.34	0.431	62	0.8%	4.65 [3.97, 5.33]
Huang and Gao.Z-Y(2),Z(3)2018	10.47	3.07	36	8.41	3.02	36	0.8%	0.67 [0.19, 1.14]
Liu .Z-Y(2),Z(3)2015	11.8	2.32	30	12.01	3.17	30	0.8%	-0.07 [-0.58, 0.43]
Wang.L-Y(2),L(3)2018	151	24	18	149	21	20	0.8%	0.09 [-0.55, 0.72]
Wang.Z-Y(2),Z(3)2018	10.3	5.6	18	8.5	6.3	20	0.8%	0.29 [-0.35, 0.94]
Wang.Z-Y(2),Z(3)2019	13.71	3.4	24	10.39	3.94	24	0.8%	0.89 [0.29, 1.48]
Wei.L-Y(2),L(2)2016	155.7	14.04	10	152	12.7	10	0.7%	0.26 [-0.62, 1.15]
Wei.Z-Y(2),Z(2)2016	6.8	4.75	10	4	3.71	10	0.7%	0.63 [-0.27, 1.53]
Wright. Z-Y(2),Z(2)2015	13	22	11	12	18	11	0.7%	0.05 [-0.79, 0.88]
Zou.Z-Y(2),Z(3)2016	9.37	3.02	42	7.71	3.06	42	0.8%	0.54 [0.11, 0.98]
Subtotal (95% CI)			**324**			**320**	**8.4%**	**1.41 [0.35, 2.47]**
Heterogeneity: Tau² = 3.09; Chi² = 306.66, df = 10 (P < 0.00001); I² = 97%								
Test for overall effect: Z = 2.60 (P = 0.009)								
Total (95% CI)			**4898**			**4667**	**100.0%**	**0.28 [0.11, 0.46]**
Heterogeneity: Tau² = 0.92; Chi² = 2044.37, df = 126 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 3.17 (P = 0.002)								
Test for subgroup differences: Chi² = 4.98, df = 1 (P = 0.03), I² = 79.9%								

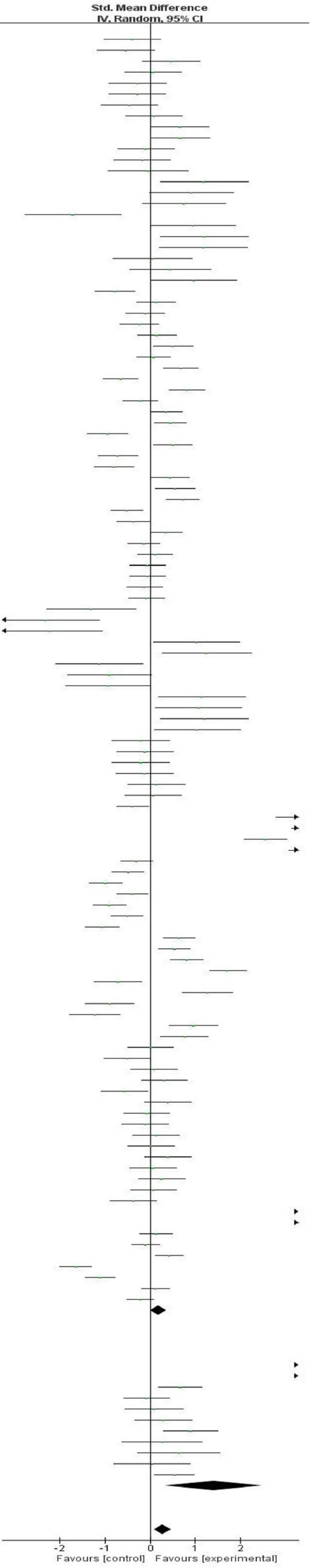

FIGURE 6
Different ages.

10.3389/fpsyg.2024.1355821

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.5.1 4-8Weeks								
Wei1,2016	6.8	4.75	10	4	3.71	10	0.7%	0.63 [-0.27, 1.53]
Wei2,2016	155.7	14.04	10	152	12.7	10	0.7%	0.26 [-0.62, 1.15]
Wright et al.1,2015	13	22	11	12	18	11	0.7%	0.05 [-0.79, 0.88]
Zheng1,2021	10.89	2.06	30	11.79	1.47	30	0.8%	-0.50 [-1.01, 0.02]
Zheng10,2021	10.96	2.2	30	10.73	3.49	30	0.8%	0.08 [-0.43, 0.58]
Zheng11,2021	10.8	3.85	30	12.15	3.34	30	0.8%	-0.37 [-0.88, 0.14]
Zheng12,2021	70.73	9.57	30	66.99	8.98	30	0.8%	0.40 [-0.11, 0.91]
Zheng13,2021	89.08	8.7	30	89.75	9.79	30	0.8%	-0.07 [-0.58, 0.43]
Zheng14,2021	112.75	12.78	30	114	10.52	30	0.8%	-0.11 [-0.61, 0.40]
Zheng15,2021	3.8	0.59	30	3.79	0.61	30	0.8%	0.02 [-0.49, 0.52]
Zheng2,2021	5.96	1.08	30	5.89	1.19	30	0.8%	0.06 [-0.45, 0.57]
Zheng3,2021	7.24	0.95	30	7.05	0.41	30	0.8%	0.26 [-0.25, 0.76]
Zheng4,2021	9.18	0.76	30	9.04	1.24	30	0.8%	0.13 [-0.37, 0.64]
Zheng5,2021	5.47	1.35	30	5.44	1.17	30	0.8%	0.02 [-0.48, 0.53]
Zheng6,2021	4.52	0.55	30	4.27	0.67	30	0.8%	0.40 [-0.11, 0.91]
Zheng7,2021	13.04	3.59	30	12.66	4.93	30	0.8%	0.09 [-0.42, 0.59]
Zheng8,2021	8.63	1.19	30	8.16	1.71	30	0.8%	0.31 [-0.19, 0.82]
Zheng9,2021	5.1	1.68	30	5.88	0.92	30	0.8%	-0.57 [-1.09, -0.05]
Subtotal (95% CI)			**481**			**481**	**14.1%**	**0.03 [-0.11, 0.17]**
Heterogeneity: Tau^2 = 0.01; Chi^2 = 20.17, df = 17 (P = 0.27); I^2 = 16%								
Test for overall effect: Z = 0.46 (P = 0.65)								
3.5.2 10-12Weeks								
Chen1,2021	9.88	2.87	20	10.1	1.7	20	0.8%	-0.09 [-0.71, 0.53]
Chen10,2021	10.29	2.42	20	10.73	2.76	20	0.8%	-0.17 [-0.79, 0.45]
Chen11,2021	99.75	10.45	20	94	13.26	20	0.8%	0.47 [-0.16, 1.10]
Chen12,2021	92.16	11.42	20	91.45	11.38	20	0.8%	0.06 [-0.56, 0.68]
Chen2,2021	6.69	0.61	20	6.87	0.69	20	0.8%	-0.27 [-0.89, 0.35]
Chen3,2021	7.34	0.64	20	7.56	0.86	20	0.8%	-0.28 [-0.91, 0.34]
Chen4,2021	6.23	1	20	5.66	0.68	20	0.8%	0.65 [0.02, 1.29]
Chen5,2021	5.67	0.68	20	5.18	0.75	20	0.8%	0.67 [0.03, 1.31]
Chen6,2021	5.77	0.81	20	6.15	0.82	20	0.8%	-0.46 [-1.09, 0.17]
Chen7,2021	6.12	0.52	20	6.05	0.9	20	0.8%	0.09 [-0.53, 0.71]
Chen8,2021	7.1	0.9	20	7.53	1.24	20	0.8%	-0.39 [-1.02, 0.24]
Chen9,2021	6.56	0.92	20	7.08	1	20	0.8%	-0.53 [-1.16, 0.10]
Ding.2021	6.95	0.669	10	6.05	0.766	10	0.7%	1.20 [0.23, 2.17]
Ding1,2021	6.2	5.266	10	3.9	4.701	10	0.7%	0.44 [-0.45, 1.33]
Ding10,2021	5.5	4.836	10	1.4	3.026	10	0.7%	0.97 [0.03, 1.91]
Ding11,2021	97.1	6.064	10	88.1	11.827	10	0.7%	0.92 [-0.01, 1.85]
Ding12,2021	81.5	8.885	10	74.9	7.923	10	0.7%	0.75 [-0.16, 1.67]
Ding2,2021	6.45	0.242	10	7.5	0.447	10	0.6%	-2.80 [-4.10, -1.49]
Ding3,2021	6.58	0.444	10	7.52	0.601	10	0.7%	-1.70 [-2.76, -0.65]
Ding4,2021	5.85	1.216	10	4.26	1.372	10	0.7%	1.17 [0.21, 2.14]
Ding5,2021	4.6	0.748	10	4.55	0.972	10	0.7%	0.06 [-0.82, 0.93]
Ding6,2021	5.9	0.733	10	5.26	0.55	10	0.7%	0.95 [0.01, 1.88]
Ding8,2021	5.51	1.018	10	5.58	1.794	10	0.7%	-0.05 [-0.92, 0.83]
Ding9,2021	7.38	1.339	10	5.56	1.58	10	0.7%	1.19 [0.22, 2.16]
Fan1,2021	6.92	4.49	42	4.91	3.26	42	0.8%	0.51 [0.07, 0.94]
Fan2,2021	78.4	11.93	42	76.98	10.21	42	0.8%	0.13 [-0.30, 0.55]
Fan3,2021	9.4	0.78	42	9.49	0.84	42	0.8%	-0.11 [-0.54, 0.32]
Fan4,2021	3.91	1.13	42	3.74	1.14	42	0.8%	0.15 [-0.28, 0.58]
Fan5,2021	8.63	1.31	42	8.95	1.34	42	0.8%	-0.24 [-0.67, 0.19]
Fan6,2021	14.98	3.68	42	18.16	4.43	42	0.8%	-0.77 [-1.22, -0.33]
Gao1,2021	7.44	4.29	59	8.4	4.45	53	0.8%	-0.22 [-0.59, 0.15]
Gao2,2021	93.69	22.98	59	78	23	53	0.8%	0.68 [0.30, 1.06]
Gao3,2021	6.49	2.47	59	4.75	1.65	53	0.8%	0.81 [0.43, 1.20]
Gao4,2021	5.84	1.31	59	6.88	1.83	53	0.8%	-0.65 [-1.04, -0.27]
Gao5,2021	5.09	4.98	59	4.78	1.48	53	0.8%	0.08 [-0.29, 0.45]
Liu 1,2014	9.88	1.26	45	9.05	1.68	42	0.8%	0.56 [0.13, 0.99]
Liu 1,2015	11.8	2.32	30	12.01	3.17	30	0.8%	-0.07 [-0.58, 0.43]
Liu 2,2014	104.4	9.92	45	99.11	11.12	42	0.8%	0.50 [0.07, 0.93]
Liu 3,2014	6.65	0.48	45	7.03	0.57	42	0.8%	-0.72 [-1.15, -0.28]
Liu 4,2014	7.41	1.97	45	6.5	2.09	42	0.8%	0.44 [0.02, 0.87]
Liu 5,2014	5.5	0.82	45	6.1	0.67	42	0.8%	-0.79 [-1.23, -0.35]
Liu 6,2014	5.02	0.83	45	5.76	0.74	42	0.8%	-0.93 [-1.37, -0.49]
Wang et al. 1,2018	10.3	5.6	18	8.5	6.3	20	0.8%	0.29 [-0.35, 0.94]
Wang1,2019	13.71	3.4	24	10.39	3.94	24	0.8%	0.89 [0.29, 1.48]
Wang2,2018	151	24	18	149	21	20	0.8%	0.09 [-0.55, 0.72]
Wu1,2015	11.4	3.28	10	8.3	1.16	10	0.7%	1.21 [0.24, 2.18]
Wu10,2015	14.7	4.03	10	11.2	2.16	10	0.7%	1.04 [0.09, 1.98]
Wu11,2015	110.5	5.15	10	106.2	2.31	10	0.7%	1.03 [0.09, 1.98]
Wu12,2015	108.9	4.45	10	104.5	1.67	10	0.7%	1.25 [0.28, 2.23]
Wu2,2015	6	0.89	10	6.8	0.36	10	0.7%	-1.13 [-2.09, -0.17]
Wu3,2015	6.6	1.34	10	7.9	0.23	10	0.7%	-1.30 [-2.28, -0.31]
Wu4,2015	7.2	1.01	10	6.3	0.33	10	0.7%	1.15 [0.19, 2.11]
Wu5,2015	6.7	0.14	10	5.1	2.02	10	0.7%	1.07 [0.12, 2.02]
Wu6,2015	4.9	1.12	10	5.7	0.45	10	0.7%	-0.90 [-1.83, 0.03]
Wu7,2015	5.2	1.71	10	6.4	0.34	10	0.7%	-0.93 [-1.87, 0.00]
Wu8,2015	5.2	1.27	10	7.5	0.45	10	0.6%	-2.31 [-3.50, -1.13]
Wu9,2015	5.4	1.34	10	7.7	0.44	10	0.6%	-2.21 [-3.37, -1.05]
Xia1,2019	7.28	3.35	21	6.82	3.37	18	0.8%	0.13 [-0.50, 0.76]
Xia2,2019	7.02	2.52	22	6.82	3.37	18	0.8%	0.07 [-0.56, 0.69]
Xia3,2019	92.29	12.02	21	95.11	14.36	18	0.8%	-0.21 [-0.84, 0.42]
Xia4,2019	93.27	16.96	22	95.11	14.36	18	0.8%	-0.11 [-0.74, 0.51]
Xia5,2019	8.38	1.36	21	8.73	2.03	18	0.8%	-0.20 [-0.83, 0.43]
Xia6,2019	8.54	1.06	22	8.73	2.03	18	0.8%	-0.12 [-0.74, 0.50]
Xu1,2021	87	2.56	67	79	1.63	64	0.8%	3.69 [3.12, 4.26]
Xu10,2021	82	2.49	67	75	1.6	64	0.8%	3.31 [2.78, 3.84]
Xu11,2021	114.2	1.74	67	108.7	2.51	64	0.8%	2.54 [2.08, 3.01]
Xu12,2021	106.4	2.6	67	98	1.94	64	0.8%	3.63 [3.07, 4.19]
Xu13,2021	7.1	0.89	67	7.3	0.36	64	0.8%	-0.29 [-0.63, 0.05]
Xu14,2021	7.5	1.34	67	7.9	0.56	64	0.8%	-0.38 [-0.73, -0.04]
Xu15,2021	6	0.76	67	6.7	1.92	64	0.8%	-0.48 [-0.83, -0.13]
Xu16,2021	6.2	1.03	67	7	0.47	64	0.8%	-0.99 [-1.35, -0.62]
Xu2,2021	7.24	1.44	67	6.1	2.08	64	0.8%	0.64 [0.28, 0.99]
Xu3,2021	5.1	1.84	67	4.2	1.45	64	0.8%	0.54 [0.19, 0.89]
Xu4,2021	9.3	2.21	67	7.9	0.97	64	0.8%	0.81 [0.45, 1.17]
Xu5,2021	7.6	1.01	67	6.3	0.31	64	0.8%	1.71 [1.31, 2.12]
Xu6,2021	6.3	2.32	67	7	0.94	64	0.8%	-0.39 [-0.74, -0.04]
Xu7,2021	6.5	1.12	67	7.8	1.71	64	0.8%	-0.90 [-1.26, -0.54]
Xu8,2021	5.2	2.12	67	6.1	1.32	64	0.8%	-0.50 [-0.85, -0.16]
Xu9,2021	5.1	1.12	67	6.2	0.94	64	0.8%	-1.06 [-1.42, -0.69]
Zhou 1,2021	5.81	1.872	60	5.54	1.958	60	0.8%	0.14 [-0.22, 0.50]
Zhou 2,2021	99.83	4.013	60	74.3	6.171	60	0.8%	4.87 [4.15, 5.60]
Zhou 3,2021	6.66	0.511	60	10.63	1.344	60	0.8%	-3.88 [-4.49, -3.27]
Zhou 4,2021	4.97	0.332	60	3.37	0.49	60	0.8%	3.80 [3.19, 4.40]
Zhou 5,2021	6.44	0.615	60	15.21	3.198	60	0.8%	-3.78 [-4.39, -3.18]
Zhou6,2021	4.51	0.537	60	13.49	4.188	60	0.8%	-2.99 [-3.51, -2.46]
Subtotal (95% CI)			**2948**			**2835**	**65.0%**	**0.14 [-0.13, 0.41]**
Heterogeneity: Tau^2 = 1.49; Chi^2 = 1841.17, df = 84 (P < 0.00001); I^2 = 95%								
Test for overall effect: Z = 1.00 (P = 0.32)								
3.5.3 16-18Weeks								
Du et al.1,2019	9.2	0.48	61	3.9	0.83	55	0.7%	7.87 [6.78, 8.96]
Du et al.2,2019	12.7	1.55	64	7.34	0.431	62	0.8%	4.65 [3.97, 5.33]
Huang and Gao1,2018	10.47	3.07	36	8.41	3.02	36	0.8%	0.67 [0.19, 1.14]
Liu1,2017	11.29	5.09	62	11.88	3.46	62	0.8%	-0.13 [-0.49, 0.22]
Liu2,2017	121.61	15.88	62	111.4	12.09	62	0.8%	0.72 [0.36, 1.08]
Liu3,2017	6.09	0.48	62	6.32	0.41	62	0.8%	-0.51 [-0.87, -0.15]
Liu4,2017	7.37	2.42	62	6.67	1.3	62	0.8%	0.36 [0.00, 0.71]
Liu5,2017	4.85	0.73	62	5.16	0.92	62	0.8%	-0.37 [-0.73, -0.02]
Wang1,2021	5.2	5	54	5.61	5.35	50	0.8%	-0.08 [-0.46, 0.31]
Wang2,2021	78.35	11.46	54	79.02	14.17	50	0.8%	-0.05 [-0.44, 0.33]
Wang3,2021	8.45	0.97	54	8.5	0.88	50	0.8%	-0.05 [-0.44, 0.33]
Wang4,2021	8.49	3.55	54	8.93	3.57	50	0.8%	-0.12 [-0.51, 0.26]
Wang5,2021	24.58	15.2	54	22.86	15.02	50	0.8%	0.11 [-0.27, 0.50]
Zhao1,2020	12.3	4.96	30	8.9	3.81	30	0.8%	0.76 [0.23, 1.28]
Zhao2,2020	97	10.81	30	85	7.75	30	0.8%	1.26 [0.70, 1.82]
Zhao3,2020	6.9	0.57	30	7.5	0.74	30	0.8%	-0.90 [-1.43, -0.36]
Zhao4,2020	5	1.01	30	4	1.06	30	0.8%	0.95 [0.42, 1.49]
Zhao5,2020	5.4	0.68	30	6.5	1.07	30	0.8%	-1.21 [-1.76, -0.66]
Zhao6,2020	6.3	1.88	30	7.9	2.56	30	0.8%	-0.70 [-1.23, -0.18]
Zhou1,2021	11.17	4.91	94	12.28	5.09	79	0.8%	-0.22 [-0.52, 0.08]
Zhou2,2021	102.26	13.69	94	96.41	14.24	79	0.8%	0.42 [0.12, 0.72]
Zhou3,2021	6.6	0.65	94	7.67	0.65	79	0.8%	-1.64 [-1.99, -1.29]
Zhou4,2021	4.34	1.78	94	4.15	1.29	79	0.8%	0.12 [-0.18, 0.42]
Zou1,2016	9.37	3.02	42	7.71	3.06	42	0.8%	0.54 [0.11, 0.98]
Subtotal (95% CI)			**1339**			**1251**	**19.2%**	**0.45 [0.02, 0.87]**
Heterogeneity: Tau^2 = 1.06; Chi^2 = 593.56, df = 23 (P < 0.00001); I^2 = 96%								
Test for overall effect: Z = 2.07 (P = 0.04)								
3.5.4 36Weeks								
Jaksic et al.2,2020	37.3	7.82	66	34.36	8.38	66	0.8%	0.36 [0.02, 0.70]
Jaksic et al.2,2020	121.98	20.44	66	112.98	19.06	66	0.8%	0.45 [0.11, 0.80]
Subtotal (95% CI)			**132**			**132**	**1.6%**	**0.41 [0.16, 0.65]**
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.14, df = 1 (P = 0.71); I^2 = 0%								
Test for overall effect: Z = 3.27 (P = 0.001)								
Total (95% CI)			**4900**			**4699**	**100.0%**	**0.19 [-0.00, 0.38]**
Heterogeneity: Tau^2 = 1.14; Chi^2 = 2462.42, df = 128 (P < 0.00001); I^2 = 95%								
Test for overall effect: Z = 1.95 (P = 0.05)								
Test for subgroup differences: Chi^2 = 8.87, df = 3 (P = 0.03), I^2 = 66.2%								

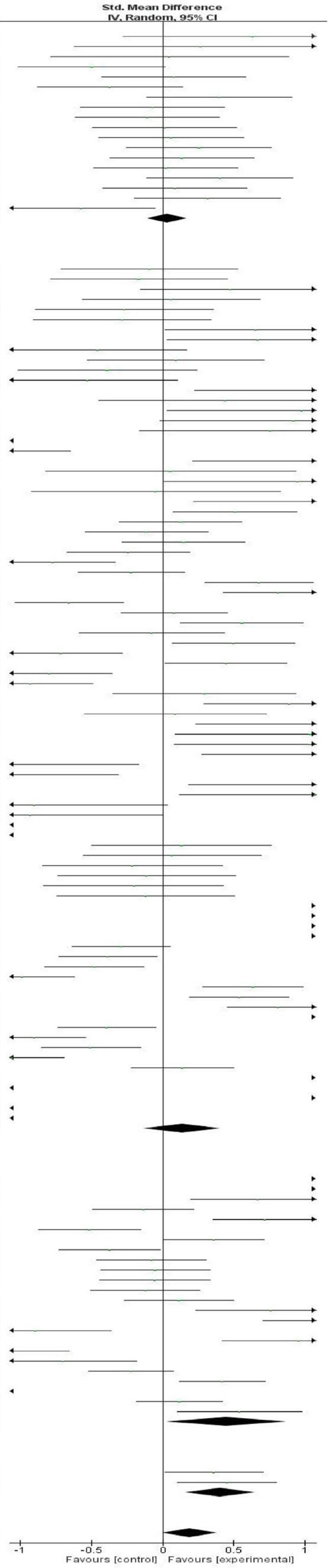

FIGURE 7
Different intervention durations.

Study or Subgroup	Control Mean	Control SD	Control Total	Experimental Mean	Experimental SD	Experimental Total	Weight	Std. Mean Difference IV, Random, 95% CI
4.4.1 1Time/Week								
Ding.H-Y(1),H(1) 2021	5.51	1.018	10	5.58	1.794	10	0.7%	-0.05 [-0.92, 0.83]
Ding.H-Y(1),H(1)2021	7.38	1.339	10	5.56	1.58	10	0.7%	1.19 [0.22, 2.16]
Ding.L-Y(1) ,L(1)2021	97.1	6.064	10	88.1	11.827	10	0.7%	0.92 [-0.01, 1.85]
Ding.L-Y(1),L(1)2021	81.5	8.885	10	74.9	7.923	10	0.7%	0.75 [-0.16, 1.67]
Ding.P-Y(1),P(1)2021	6.58	0.444	10	7.52	0.601	10	0.7%	-1.70 [-2.76, -0.65]
Ding.S-Y(1),S(1) 2021	5.9	0.733	10	5.26	0.55	10	0.7%	0.95 [0.01, 1.88]
Ding.S-Y(1),S(1)2021	6.95	0.669	10	6.05	0.766	10	0.7%	1.20 [0.23, 2.17]
Ding.W-Y(1) ,W(1)2021	5.85	1.216	10	4.26	1.372	10	0.7%	1.17 [0.21, 2.14]
Ding.W-Y(1),W(1)2021	4.6	0.748	10	4.55	0.972	10	0.7%	0.06 [-0.82, 0.93]
Ding.Z-Y(1),Z(1) 2021	6.2	5.266	10	3.9	4.701	10	0.7%	0.44 [-0.45, 1.33]
Ding.Z-Y(1),Z(1)2021	5.5	4.836	10	1.4	3.026	10	0.7%	0.97 [0.03, 1.91]
Du et al.Z-Y(2),Z(1) 2019	9.2	0.48	61	3.9	0.83	55	0.7%	7.87 [6.78, 8.96]
Du et al.Z-Y(2),Z(1)2019	12.7	1.55	64	7.34	0.431	62	0.8%	4.65 [3.97, 5.33]
Xia.L-Y(1),L(1)2019	92.29	12.02	21	95.11	14.36	18	0.8%	-0.21 [-0.84, 0.42]
Xia.P-Y(1),P(1)2019	8.38	1.36	21	8.73	2.03	18	0.8%	-0.20 [-0.83, 0.43]
Xia.Z-Y(1),Z(1) 2019	7.28	3.35	21	6.82	3.37	18	0.8%	0.13 [-0.50, 0.76]
Xia.Z-Y(1),Z(1)2019	7.02	2.52	22	6.82	3.37	18	0.8%	0.07 [-0.56, 0.69]
Subtotal (95% CI)			**320**			**299**	**12.7%**	**1.06 [0.14, 1.98]**
Heterogeneity: Tau² = 3.56; Chi² = 342.81, df = 16 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 2.26 (P = 0.02)								
4.4.2 2Times/Week								
Gao.H-Y(1),H(2)2021	5.09	4.98	59	4.78	1.48	53	0.8%	0.08 [-0.29, 0.45]
Gao.L-Y(1),L(2)2021	93.69	22.98	59	78	23	53	0.8%	0.68 [0.30, 1.06]
Gao.W-Y(1),W(2)2021	6.49	2.47	59	4.75	1.65	53	0.8%	0.81 [0.43, 1.20]
Gao.Z-Y(1),Z(2)2021	7.44	4.29	59	8.4	4.45	53	0.8%	-0.22 [-0.59, 0.15]
Jaksic et al.Z-Y(1),Z(2)2020	37.3	7.82	66	34.36	8.38	66	0.8%	0.36 [0.02, 0.70]
Jaksic.L-Y(1),L(2)2020	121.98	20.44	66	112.98	19.06	66	0.8%	0.45 [0.11, 0.80]
Liu.L-Y(1),L(2)2017	121.61	15.88	62	111.4	12.09	62	0.8%	0.72 [0.36, 1.08]
Liu.S-Y(1),S(2)2017	4.85	0.73	62	5.16	0.92	62	0.8%	-0.37 [-0.73, -0.02]
Liu.W-Y(1),W(2)2017	7.37	2.42	62	6.67	1.3	62	0.8%	0.36 [0.00, 0.71]
Liu.Z-Y(1),Z(2)2017	11.29	5.09	62	11.88	3.46	62	0.8%	-0.13 [-0.49, 0.22]
Wei.L-Y(2),L(2)2016	155.7	14.04	10	152	12.7	10	0.7%	0.26 [-0.62, 1.15]
Wei.Z-Y(2),Z(2)2016	6.8	4.75	10	4	3.71	10	0.7%	0.63 [-0.27, 1.53]
Wright. Z-Y(2),Z(2)2015	13	22	11	12	18	11	0.8%	0.05 [-0.79, 0.88]
Xia.L-Y(1),L(2)2019	93.27	16.96	22	95.11	14.36	18	0.8%	-0.11 [-0.74, 0.51]
Xia.P-Y(1),P(2)2019	8.54	1.06	22	8.73	2.03	18	0.8%	-0.12 [-0.74, 0.50]
Zheng. W-Y(1),W(2)2021	3.8	0.59	30	3.79	0.61	30	0.8%	0.02 [-0.49, 0.52]
Zheng. Z-Y(1),Z(2) 2021	10.89	2.06	30	11.79	1.47	30	0.8%	-0.50 [-1.01, 0.02]
Zheng.H-Y(1) ,H(2)2021	13.04	3.59	30	12.66	4.93	30	0.8%	0.09 [-0.42, 0.59]
Zheng.L-Y(1) ,L(2)2021	70.73	9.57	30	66.99	8.98	30	0.8%	0.40 [-0.11, 0.91]
Zheng.L-Y(1),L(2) 2021	89.08	8.7	30	89.75	9.79	30	0.8%	-0.07 [-0.58, 0.43]
Zheng.L-Y(1),L(2)2021	112.75	12.78	30	114	10.52	30	0.8%	-0.11 [-0.61, 0.40]
Zheng.S-Y(1), S(2)2021	9.18	0.76	30	9.04	1.24	30	0.8%	0.13 [-0.37, 0.64]
Zheng.S-Y(1),S(2) 2021	5.47	1.35	30	5.44	1.17	30	0.8%	0.02 [-0.48, 0.53]
Zheng.S-Y(1),S(2)2021	4.52	0.55	30	4.27	0.67	30	0.8%	0.40 [-0.11, 0.91]
Zheng.W-Y(1), W(2)2021	5.96	1.08	30	5.89	1.19	30	0.8%	0.06 [-0.45, 0.57]
Zheng.W-Y(1),W(2)2021	7.24	0.95	30	7.05	0.41	30	0.8%	0.26 [-0.25, 0.76]
Zheng.Z-Y(1),Z(2) 2021	10.96	2.2	30	10.73	3.49	30	0.8%	0.08 [-0.43, 0.58]
Zheng.Z-Y(1),Z(2)2021	10.8	3.85	30	12.15	3.34	30	0.8%	-0.37 [-0.88, 0.14]
Subtotal (95% CI)			**1081**			**1049**	**23.0%**	**0.14 [0.01, 0.28]**
Heterogeneity: Tau² = 0.08; Chi² = 65.50, df = 27 (P < 0.0001); I² = 59%								
Test for overall effect: Z = 2.06 (P = 0.04)								
4.4.3 3Times/Week								
Chen.H-Y(1),H(3) 2021	7.1	0.9	20	7.53	1.24	20	0.8%	-0.39 [-1.02, 0.24]
Chen.H-Y(1),H(3)2021	6.56	0.92	20	7.08	1	20	0.8%	-0.53 [-1.16, 0.10]
Chen.L-Y(1) ,L(3)2021	99.75	10.45	20	94	13.26	20	0.8%	0.47 [-0.16, 1.10]
Chen.L-Y(1),L(3)2021	92.16	11.42	20	91.45	11.38	20	0.8%	0.06 [-0.56, 0.68]
Chen.P-Y(1),P(3) 2021	6.69	0.61	20	6.87	0.69	20	0.8%	-0.27 [-0.89, 0.35]
Chen.P-Y(1),P(3)2021	7.34	0.64	20	7.56	0.86	20	0.8%	-0.28 [-0.91, 0.34]
Chen.S-Y(1),S(3) 2021	5.77	0.81	20	6.15	0.82	20	0.8%	-0.46 [-1.09, 0.17]
Chen.S-Y(1),S(3)2021	6.12	0.52	20	6.05	0.9	20	0.8%	0.09 [-0.53, 0.71]
Chen.W-Y(1),W(3) 2021	6.23	1	20	5.66	0.68	20	0.8%	0.65 [0.02, 1.29]
Chen.W-Y(1),W(3)2021	5.67	0.68	20	5.18	0.75	20	0.8%	0.67 [0.03, 1.31]
Chen.Z-Y(1),Z(3) 2021	9.88	2.87	20	10.1	1.7	20	0.8%	-0.09 [-0.71, 0.53]
Chen.Z-Y(1),Z(3)2021	10.29	2.42	20	10.73	2.76	20	0.8%	-0.17 [-0.79, 0.45]
Fan.H-Y(1),H(3)2021	14.98	3.68	42	18.16	4.43	42	0.8%	-0.77 [-1.22, -0.33]
Fan.L-Y(1),L(3)2021	78.4	11.93	42	76.98	10.21	42	0.8%	0.13 [-0.30, 0.55]
Fan.P-Y(1),P(3)2021	9.4	0.78	42	9.49	0.84	42	0.8%	-0.11 [-0.54, 0.32]
Fan.S-Y(1),S(3)2021	8.63	1.31	42	8.95	1.34	42	0.8%	-0.24 [-0.67, 0.19]
Fan.W-Y(1),W(3)2021	3.91	1.13	42	3.74	1.14	42	0.8%	0.15 [-0.28, 0.58]
Fan.Z-Y(1),Z(3)2021	6.92	4.49	42	4.91	3.26	42	0.8%	0.51 [0.07, 0.94]
Huang and Gao.Z-Y(2),Z(3)2018	10.47	3.07	36	8.41	3.02	36	0.8%	0.67 [0.19, 1.14]
Liu .H-Y(1),H(3)2014	5.02	0.83	45	5.76	0.74	42	0.8%	-0.93 [-1.37, -0.49]
Liu .L-Y(1),L(3)2014	104.4	9.92	45	99.11	11.12	42	0.8%	0.50 [0.07, 0.93]
Liu .P-Y(1),P(3)2014	6.65	0.48	45	7.03	0.57	42	0.8%	-0.72 [-1.15, -0.28]
Liu .S-Y(1),S(3)2014	5.5	0.82	45	6.1	0.67	42	0.8%	-0.79 [-1.23, -0.35]
Liu .W-Y(1),W(3)2014	7.41	1.97	45	6.5	2.09	42	0.8%	0.44 [0.02, 0.87]
Liu .Z-Y(1),Z(3)2014	9.88	1.26	45	9.05	1.68	42	0.8%	0.56 [0.13, 0.99]
Liu .Z-Y(2),Z(3)2015	11.8	2.32	30	12.01	3.17	30	0.8%	-0.07 [-0.58, 0.43]
Wang.H-Y(1),H(3)2021	24.58	15.2	54	22.86	15.02	50	0.8%	0.11 [-0.27, 0.50]
Wang.L-Y(1),L(3)2021	78.35	11.46	54	79.02	14.17	50	0.8%	-0.05 [-0.44, 0.33]
Wang.L-Y(2),L(3)2018	151	24	18	149	21	20	0.8%	0.09 [-0.55, 0.72]
Wang.P-Y(1),P(3)2021	8.45	0.97	54	8.5	0.88	50	0.8%	-0.05 [-0.44, 0.33]
Wang.S-Y(1),S(3)2021	8.49	3.55	54	8.93	3.57	50	0.8%	-0.12 [-0.51, 0.26]
Wang.Z-Y(1),Z(3)2021	5.2	5	54	5.61	5.35	50	0.8%	-0.08 [-0.46, 0.31]
Wang.Z-Y(2),Z(3)2018	10.3	5.6	18	8.5	6.3	20	0.8%	0.29 [-0.35, 0.94]
Wang.Z-Y(2),Z(3)2019	13.71	3.4	24	10.39	3.94	24	0.8%	0.89 [0.29, 1.48]
Wu .P-Y(1),P(3) 2015	6.6	1.34	10	7.9	0.23	10	0.7%	-1.30 [-2.28, -0.31]
Wu.H-Y(1),H(3) 2015	5.2	1.27	10	7.5	0.45	10		Not estimable
Wu.H-Y(1),H(3)2015	5.4	1.34	10	7.7	0.44	10		Not estimable
Wu.L-Y(1),L(3) 2015	110.5	5.15	10	106.2	2.31	10	0.7%	1.03 [0.09, 1.98]
Wu.L-Y(1),L(3)2015	108.9	4.45	10	104.5	1.67	10	0.7%	1.25 [0.28, 2.23]
Wu.P-Y(1),P(3) 2015	6	0.89	10	6.8	0.36	10	0.7%	-1.13 [-2.09, -0.17]
Wu.S-Y(1),S(3) 2015	4.9	1.12	10	5.7	0.45	10	0.7%	-0.90 [-1.83, 0.03]
Wu.S-Y(1),S(3)2015	5.2	1.71	10	6.4	0.34	10	0.7%	-0.93 [-1.87, 0.00]
Wu.W-Y(1) ,W(3)2015	7.2	1.01	10	6.3	0.33	10	0.7%	1.15 [0.19, 2.11]
Wu.W-Y(1),W(3)2015	6.7	0.14	10	5.1	2.02	10	0.7%	1.07 [0.12, 2.02]
Wu.Z-Y(1),Z(3) 2015	11.4	3.28	10	8.3	1.16	10	0.7%	1.21 [0.24, 2.18]
Wu.Z-Y(1),Z(3)2015	14.7	4.03	10	11.2	2.16	10	0.7%	1.04 [0.09, 1.98]
Xu .P-Y(1), P(3) 2021	7.5	1.34	67	7.9	0.56	64	0.8%	-0.38 [-0.73, -0.04]
Xu. L-Y(1),L(3) 2021	82	2.49	67	75	1.6	64	0.8%	3.31 [2.78, 3.84]
Xu.L-Y(1), L(3) 2021	87	2.56	67	79	1.63	64	0.8%	3.69 [3.12, 4.26]
Xu.L-Y(1),L(3) 2021	114.2	1.74	67	108.7	2.51	64	0.8%	2.54 [2.08, 3.01]
Xu.L-Y(1),L(3)2021	106.4	2.6	67	98	1.94	64	0.8%	3.63 [3.07, 4.19]
Xu.P-Y(1), P(3) 2021	7.1	0.89	67	7.3	0.36	64	0.8%	-0.29 [-0.63, 0.05]
Xu.P-Y(1),P(3) 2021	6	0.76	67	6.7	1.92	64	0.8%	-0.48 [-0.83, -0.13]
Xu.P-Y(1),P(3)2021	6.2	1.03	67	7	0.47	64	0.8%	-0.99 [-1.35, -0.62]
Xu.S-Y (1),S(3)2021	6.3	2.32	67	7	0.94	64	0.8%	-0.39 [-0.74, -0.04]
Xu.S-Y(1), S(3) 2021	6.5	1.12	67	7.8	1.71	64	0.8%	-0.90 [-1.26, -0.54]
Xu.S-Y(1),S(3) 2021	5.2	2.12	67	6.1	1.32	64	0.8%	-0.50 [-0.85, -0.16]
Xu.S-Y(1),S(3)2021	5.1	1.12	67	6.2	0.94	64	0.8%	-1.06 [-1.42, -0.69]
Xu.W-Y(1), W(3) 2021	7.24	1.44	67	6.1	2.08	64	0.8%	0.64 [0.28, 0.99]
Xu.W-Y(1), W(3)2021	5.1	1.84	67	4.2	1.45	64	0.8%	0.54 [0.19, 0.89]
Xu.W-Y(1),W(3) 2021	9.3	2.21	67	7.9	0.97	64	0.8%	0.81 [0.45, 1.17]
Xu.W-Y(1),W(3)2021	7.6	1.01	67	6.3	0.31	64	0.8%	1.71 [1.31, 2.12]
Zhao.H-Y(1),H(3)2020	6.3	1.88	30	7.9	2.56	30	0.8%	-0.70 [-1.23, -0.18]
Zhao.L-Y(1),L(3)2020	97	10.81	30	85	7.75	30	0.8%	1.26 [0.70, 1.82]
Zhao.P-Y(1),P(3)2020	6.9	0.57	30	7.5	0.74	30	0.8%	-0.90 [-1.43, -0.36]
Zhao.S-Y(1),S(3)2020	5.4	0.68	30	6.5	1.07	30	0.8%	-1.21 [-1.76, -0.66]
Zhao.W-Y(1),W(3)2020	5	1.01	30	4	1.06	30	0.8%	0.95 [0.42, 1.49]
Zhao.Z-Y(1),Z(3)2020	12.3	4.96	30	8.9	3.81	30	0.8%	0.76 [0.23, 1.28]
Zhou .H-Y(1),H(3)2021	4.51	0.537	60	13.49	4.188	60	0.8%	-2.99 [-3.51, -2.46]
Zhou .L-Y(1),L(3)2021	99.83	4.013	60	74.3	6.171	60	0.8%	4.87 [4.15, 5.60]
Zhou .P-Y(1),P(3)2021	6.66	0.511	60	10.63	1.344	60	0.8%	-3.88 [-4.49, -3.27]
Zhou .S-Y(1),S(3)2021	6.44	0.615	60	15.21	3.198	60	0.8%	-3.78 [-4.39, -3.18]
Zhou .W-Y(1),W(3)2021	4.97	0.332	60	3.37	0.49	60	0.8%	3.80 [3.19, 4.40]
Zhou .Z-Y(1),Z(3)2021	5.81	1.872	60	5.54	1.958	60	0.8%	0.14 [-0.22, 0.50]
Zhou.H-Y(1),H(3)2021	7.43	3.37	94	7.82	4.35	79	0.9%	-0.10 [-0.40, 0.20]
Zhou.L-Y(1),L(3)2021	102.26	13.69	94	96.41	14.24	79	0.9%	0.42 [0.12, 0.72]
Zhou.P-Y(1),P(3)2021	6.6	0.65	94	7.67	0.65	79	0.8%	-1.64 [-1.99, -1.29]
Zhou.S-Y(1),S(3)2021	5.03	0.54	94	6.6	2.03	79	0.9%	-1.09 [-1.42, -0.77]
Zhou.W-Y(1),W(3)2021	4.34	1.78	94	4.15	1.29	79	0.9%	0.12 [-0.18, 0.42]
Zhou.Z-Y(1),Z(3)2021	11.17	4.91	94	12.28	5.09	79	0.9%	-0.22 [-0.52, 0.08]
Zou.Z-Y(2),Z(3)2016	9.37	3.02	42	7.71	3.06	42	0.8%	0.54 [0.11, 0.98]
Subtotal (95% CI)			**3476**			**3304**	**64.3%**	**0.13 [-0.13, 0.39]**
Heterogeneity: Tau² = 1.32; Chi² = 1949.78, df = 78 (P < 0.00001); I² = 96%								
Test for overall effect: Z = 0.98 (P = 0.33)								
Total (95% CI)			**4877**			**4652**	**100.0%**	**0.25 [0.05, 0.44]**
Heterogeneity: Tau² = 1.14; Chi² = 2434.17, df = 123 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 2.49 (P = 0.01)								
Test for subgroup differences: Chi² = 3.77, df = 2 (P = 0.15), I² = 47.0%								

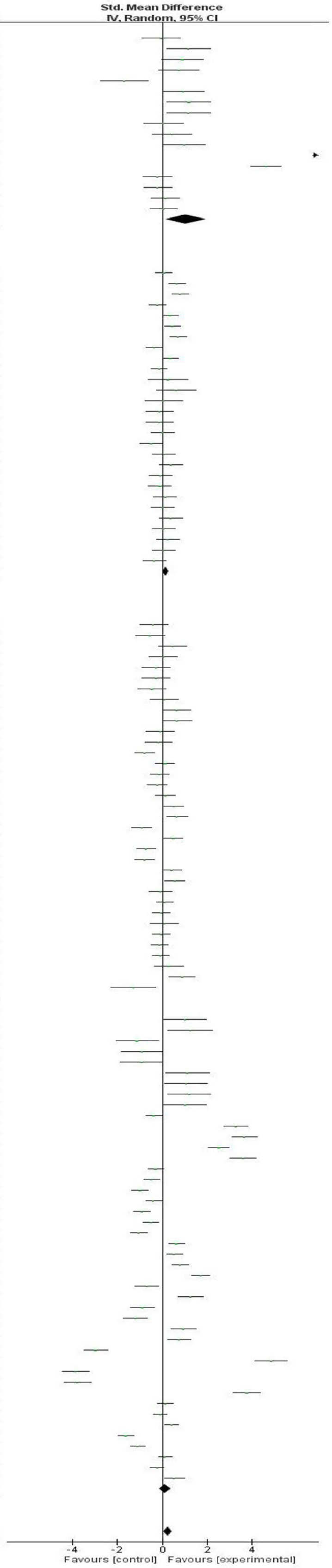

FIGURE 8
Different intervention frequencies.

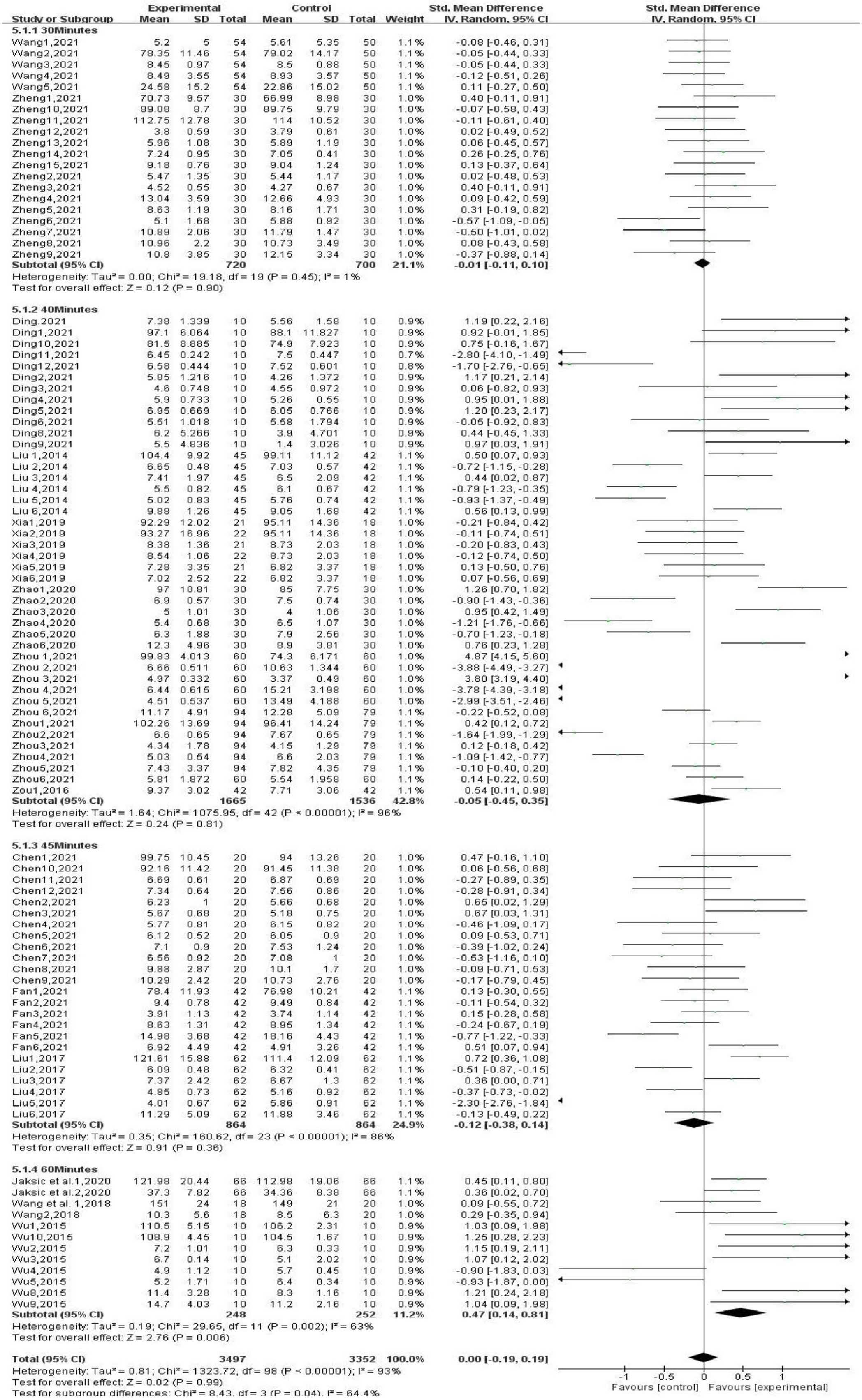

FIGURE 9
Different single-session durations.

4.4 Effects of different intervention frequencies on children's physical fitness

Gross movement intervention once a week had the most significant impact on the physical fitness of children aged 3–10 years, indicating that low-frequency interventions may be more helpful for improving children's physical fitness, which is similar to the findings of some related studies (Granacher et al., 2016; Wu et al., 2021). Some studies have shown that intervention frequencies of 2–3 times per week (Latorre Román et al., 2017; Wu et al., 2023) and 4–5 times per week (Wang et al., 2021) have the greatest effects. However, the subjects of the interventions, the duration of the interventions and the durations of the single sessions were not the same in these studies. The frequency of intervention is affected by a variety of factors, but we must consider that the purpose of any intervention is not only to improve children's physical fitness but also to motivate children to actively change unhealthy behaviors or habits (e.g., sitting for a long time) outside the intervention (Wang et al., 2021; Sheng et al., 2023), thus encouraging them to actively participate in physical activities. These findings need to be confirmed by more empirical studies.

4.5 Effects of different single-session durations on children's physical fitness

Gross movement interventions lasting for 60 min per session had the greatest effect on the physical fitness of children aged 3–10 years, which is consistent with the results of most studies (Logan et al., 2012; Zhang et al., 2017; Shi, 2022; Shen and Dan, 2023). In 2022, China issued the Guidelines for Quality Assessment of Kindergarten Care Education, stating that children should engage in at least 60 min of physical activity per day (Ministry of Education, 2022). The results obtained in this study are consistent with the recommendations of those guidelines. However, some studies have shown that a single intervention duration of 30–40 min has the greatest effect (Xin et al., 2019) because children have short attention spans (Riethmuller et al., 2009). Overly long interventions are likely to result in children losing their focus (Logan et al., 2012). Overall, the current study still needs to further explore the critical value of the duration of a single intervention on physical activity. This may also account for the actual intervention process; for example, in an activity intervention, the actual gross movement practice time may only be two-thirds of the total time when accounting for warm-ups, recovery and rest (Brian et al., 2017). Additionally, the physiological and psychological characteristics of children should be considered in the design of intervention programs, focusing on gross movement interventions in different situations.

5 Research significance and future research

5.1 Theoretical significance

The decline in children's physical fitness has become a global concern, engaging the attention of various sectors worldwide (Burns et al., 2018; Godoy-Cumillaf et al., 2021; Qu, 2021). This concern spans numerous countries, including China (National Health Monitoring Centre, 2022), Switzerland (Tomkinson, 2007), Russia (Malina and Katzmarzyk, 2006), Canada (Tremblay et al., 2010), and Spain (Moliner-Urdiales et al., 2010). The impact of children's physical fitness levels on preventing and ameliorating conditions such as obesity and cardiovascular diseases is of paramount importance (Smith et al., 2014; Al-Mallah et al., 2018; Elagizi et al., 2018; Mintjens et al., 2018; Henriksson et al., 2020). However, recent research has predominantly focused on identifying correlations between different gross movements and children's physical fitness (Foulkes et al., 2021; Liu et al., 2023) or differential performance (Haugen and Johansen, 2018; Zheng et al., 2022). There is a notable gap in the exploration of the maximum effect sizes of gross movement interventions in enhancing children's fitness. Acknowledging the pressing need for the development of children's physical fitness, this study thoroughly investigated the optimal effect sizes of gross movement interventions for children aged 3–10 years from various perspectives. These include physical fitness components, age groups, intervention duration, intervention frequency, and single-session duration. This study provides a theoretical reference for the formulation of interventions to enhance children's physical fitness. Moreover, this research leverages findings from diverse fields, such as health, sports, and education, as primary data. By adopting an interdisciplinary approach encompassing kinesiology and education, this study involved a systematic review to strategically address contemporary issues that scholars are currently focusing on, providing theoretical guidance for related fields of study.

5.2 Practical significance

Practical evidence attests to the effectiveness of gross movement interventions in enhancing children's physical fitness, addressing health concerns such as childhood obesity and cardiovascular issues (Okely et al., 2004; Barnett et al., 2008; Robinson et al., 2015; Ma and Song, 2017; Pu and Yang, 2017; Hao, 2018; Li et al., 2019; Wang et al., 2019). However, the optimal organization of gross movement interventions for enhancing children's physical fitness remains a pivotal area of inquiry. Questions surrounding which age group benefits most from the impact of gross movement interventions on physical fitness and which specific physical fitness components show the most significant improvement necessitate thorough exploration. In light of these considerations, the findings of this study offer scientific intervention guidance for enhancing children's physical fitness, offering benefits to society, educational institutions, and families. First, during childhood, emphasis should be placed on practicing gross movements, given that they have a significant impact on improving children's physical fitness, and this positive correlation remains as children grow older. Second, the cultivation of explosive strength in children is of paramount importance. Focus on enhancing children's explosive strength through tailored gross movement interventions, including movements such as tuck jumps and competitive rope climbing, can effectively enhance their explosive strength. Third, the age bracket of 7–10 years emerges as the period when children experience the most rapid improvement in physical fitness, although attention should be given to factors such as training frequency and duration.

Fourth, a gross movement intervention with a 16- to 18-week duration has been shown to be effective in enhancing children's physical fitness, contributing to the refinement of their skills and cognitive abilities. Fifth, recognizing the impact of unhealthy habits or behaviors on children's physical fitness is crucial, and a weekly session of gross movements is deemed optimal for the most pronounced effects on enhancing children's physical fitness. Finally, judiciously arranging the session duration to be 60 min per session is shown to be optimal for improving children's physical fitness. In summary, the findings of this study provide critical practical references for effectively enhancing children's physical fitness. Societal, educational, and familial entities should prioritize the influential role of gross movements in improving children's physical fitness and implement effective measures to prevent childhood physical illnesses, ultimately reducing the global incidence of developmental disorders in children.

5.3 Future research

In a follow-up study, this research group will further explore the following: ① the ongoing impact of gross movement interventions on children's physical fitness; ② the effects of different gross movement interventions on different physical qualities; and ③ the effect of different total intervention durations on children's physical fitness and related issues.

6 Limitations

This study did not discuss the subsequent effects of gross movement interventions on children's physical fitness. In addition, gross movements are mainly completed using large muscle groups. This study did not classify gross movements by muscle groups, nor did it explore the effects of different large muscle groups on physical fitness. Second, the literature included in this study did not account for the effects of sex, country, total duration of intervention across age groups, family environment, nutrition and health status, teacher training level or other factors related to on children's physical fitness, which may have led to certain biases in the results. Therefore, additional studies are needed to overcome these limitations and validate the current findings.

7 Conclusion

The results of this meta-analysis show that gross movement interventions have a positive impact on the physical fitness of children aged 3–10 years, especially on explosive power. Specifically, gross movement interventions had stronger effects on the physical fitness of children aged 9–10 years. Additionally, the optimal intervention parameters include one intervention per week, 60 min per session, and a total intervention duration of 16–18 weeks.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

LH: Writing – review and editing, Writing – original draft, Visualization, Resources, Methodology, Investigation, Funding acquisition, Data curation. SW: Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Writing – review and editing. QL: Formal analysis, Conceptualization, Writing – review and editing. GN: Writing – review and editing, Formal analysis, Investigation, Funding acquisition.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Al-Mallah, M. H., Sakr, S., and Al-Qunaibet, A. (2018). Cardiorespiratory fitness and cardiovascular disease prevention: An update. *Curr. Atheroscler. Rep.* 20:1. doi: 10.1007/s11883-018-0711-4

Angilley, H., and Haggas, S. (2009). Physical fitness in children with movement difficulties. *Physiotherapy* 95, 144–146. doi: 10.1016/j.physio.2008.12.002

Barnett, L. M., Morgan, P. J., van Beurden, E., and Beard, J. R. (2008). Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: A longitudinal assessment. *Int. J. Behav. Nutr. Phys. Act.* 5:40. doi: 10.1186/1479-5868-5-40

Bellows, L. L., Davies, P. L., Anderson, J., and Kennedy, C. (2013). Effectiveness of a physical activity intervention for head start preschoolers: A randomized intervention study. *Am. J. Occup. Ther.* 67, 28–36. doi: 10.5014/ajot.2013.005777

Brandes, M. (2012). Körperliche aktivität oder fitness: Was ist wichtiger für die gesundheit? [The importance of physical activity and fitness for human health]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 55, 96–101. doi: 10.1007/s00103-011-1395-x

Brian, A., Goodway, J. D., Logan, J. A., and Sutherland, S. (2017). SKIPing with head start teachers: Influence of T-SKIP on object-control skills. *Res. Q. Exerc. Sport* 88, 479–491. doi: 10.1080/02701367.2017.1375077

Burns, R. D., Brusseau, T. A., and Fu, Y. (2018). Moderators of school-based physical activity interventions on cardiorespiratory endurance in primary school-aged children: A meta-regression. *Int. J. Environ. Res. Public Health* 15:1764. doi: 10.3390/ijerph15081764

Chen, L. (2022). *A study on the intervention effect of sports games based on movement development on children's physical fitness*. M.A. thesis. Hainan: Hainan Normal University.

Chen, M. D., Yu, D. Z., and Yu, B. (1993). *Practical physique*. Beijing: Beijing Medical University and Peking Union Medical University Joint Press.

Chen, T., and Gu, S. (2022). Effects of air volleyball game teaching on basic motor skills and physical health of children aged 4-6. *Chin. Sch. Health* 11, 1720–1724.

Chen, Y. Z., Yin, J., and Peng, Z. C. (2021). Effects of FIFA11+Kids intervention on physical fitness of 9∼10 year old children. *J. Beijing Univers. Sport* 44, 71–80. doi: 10.19582/j.cnki.11-3785/g8.2021.11.008

Chow, B. C., and Louie, L. H. (2013). Difference in children's gross motor skills between two types of preschools. *Percept. Motor Skills* 116, 253–261. doi: 10.2466/25.06.10.PMS.116.1.253-261

Ding, W. (2021). *An Empirical Study of small basketball activities on physical fitness development of 4-6 year old children from the perspective of movement development*. M.A. thesis. Chengdu: Chengdu University of Physical Education.

Dong, L. L., Chen, L., and Liu, Y. (2022). Effects of different exercise methods on physical health of children and adolescents. *Chin. Sports Sci. Technol.* 12, 28–36. doi: 10.16470/j.csst.2022024

Du, J., Du, P., Ouyang, N. L., Zuo, H. Y., and Zhao, J. (2019). An empirical study on the effect of functional training on physical fitness of primary school students. *Phys. Educ.* 1, 33–35.

Elagizi, A., Kachur, S., Lavie, C. J., Carbone, S., Pandey, A., Ortega, F. B., et al. (2018). An overview and update on obesity and the obesity paradox in cardiovascular diseases. *Progr. Cardiovasc. Dis.* 61, 142–150. doi: 10.1016/j.pcad.2018.07.003

Fan, R. H. (2022). *A study on the influence of functional sports games on the physical fitness of 4-5 year old children*. M.A. thesis. Qufu: Qufu Normal University.

Fang, H., Quan, M., Zhou, T., Sun, S., Zhang, J., Zhang, H., et al. (2017). Relationship between physical activity and physical fitness in preschool children: A cross-sectional study. *Biomed. Res. Int.* 2017:9314026. doi: 10.1155/2017/9314026

Fisher, A., Boyle, J. M., Paton, J. Y., Tomporowski, P., Watson, C., McColl, J. H., et al. (2011). Effects of a physical education intervention on cognitive function in young children: Randomized controlled pilot study. *BMC Pediatr.* 11:97. doi: 10.1186/1471-2431-11-97

Foulkes, J. D., Knowles, Z., Fairclough, S. J., Stratton, G., O'Dwyer, M. V., and Foweather, L. (2021). Is foundational movement skill competency important for keeping children physically active and at a healthy weight? *Int. J. Environ. Res. Public Health* 19:105. doi: 10.3390/ijerph19010105

Gao, Y. (2021). *A study on the influence of gross motor development on the physical fitness of 3-6 year old children*. M.A. thesis. Henan: Henan University.

Godoy-Cumillaf, A., Bizzozero-Peroni, B., Tomkinson, G. R., and Brazo-Sayavera, J. (2021). Physical fitness of Latin America children and adolescents: A protocol for a systematic review and meta-analysis. *BMJ Open* 11:e047122. doi: 10.1136/bmjopen-2020-047122

Godoy-Cumillaf, A., Bruneau-Chávez, J., Fuentes-Merino, P., Vásquez-Gómez, J., Sánchez-López, M., Alvárez-Bueno, C., et al. (2020). Reference values for fitness level and gross motor skills of 4-6-year-old Chilean children. *Int. J. Environ. Res. Public Health* 17:797. doi: 10.3390/ijerph17030797

Granacher, U., Lesinski, M., Büsch, D., Muehlbauer, T., Prieske, O., Puta, C., et al. (2016). Effects of resistance training in youth athletes on muscular fitness and athletic performance: A conceptual model for long-term athlete development. *Front. Physiol.* 7:164. doi: 10.3389/fphys.2016.00164

Gulías-González, R., Sánchez-López, M., Olivas-Bravo, Á, Solera-Martínez, M., and Martínez-Vizcaíno, V. (2014). Physical fitness in Spanish schoolchildren aged 6-12 years: Reference values of the battery EUROFIT and associated cardiovascular risk. *J. Sch. Health* 84, 625–635. doi: 10.1111/josh.12192

Haga, M. (2009). Physical fitness in children with high motor competence is different from that in children with low motor competence. *Phys. Ther.* 89, 1089–1097. doi: 10.2522/ptj.20090052

Hands, B. (2008). Changes in motor skill and fitness measures among children with high and low motor competence: A five-year longitudinal study. *J. Sci. Med. Sport* 11, 155–162. doi: 10.1016/j.jsams.2007.02.012

Hao, X. C. (2018). The track, focus and trend of research on infant sports in China. *J. Phys. Educ. Sports* 5, 109–113. doi: 10.16237/j.cnki.cn44-1404/g8.2018.05.011

Haugen, T., and Johansen, B. T. (2018). Difference in physical fitness in children with initially high and low gross motor competence: A ten-year follow-up study. *Hum. Move. Sci.* 62, 143–149. doi: 10.1016/j.humov.2018.10.007

Haywood, K. M., and Gallahue, D. L. (2014). *Lifespan motor development*. Champaign IL: Human kinetics.

He, Q. (2017). Research progress and future trend of physical fitness in China in recent 20 years. *Sports Cult. Guide* 2017, 201–206.

Henriksson, H., Henriksson, P., Tynelius, P., Ekstedt, M., Berglind, D., Labayen, I., et al. (2020). Cardiorespiratory fitness, muscular strength, and obesity in adolescence and later chronic disability due to cardiovascular disease: A cohort study of 1 million men. *Eur. Heart J.* 41, 1503–1510. doi: 10.1093/eurheartj/ehz774

Huang, R. Q. (2000). *Dictionary of modern industrial language*. Haikou: Nanhai Publishing Company, 717.

Huang, Y., and Gao, Y. (2018). An experimental study on the development of agility and coordination by means of functional physical training: A case study of Grade 4 in primary school. *Contemp. Sports Sci. Technol.* 35, 235–237+239. doi: 10.16655/j

Jaksic, D., Mandic, S., Maksimovic, N., Milosevic, Z., Roklicer, R., Vukovic, J., et al. (2020). Effects of a nine-month physical activity intervention on morphological characteristics and motor and cognitive skills of preschool children. *Int. J. Environ. Res. Public Health* 17:6609. doi: 10.3390/ijerph17186609

Kim, E., Won, Y., and Shin, J. (2021). Analysis of children's physical characteristics based on clustering analysis. *Children* 8:485. doi: 10.3390/children8060485

Latorre Román, P. Á, Moreno Del Castillo, R., Lucena Zurita, M., Salas Sánchez, J., García-Pinillos, F., and Mora López, D. (2017). Physical fitness in preschool children: Association with sex, age and weight status. *Child Care Health Dev.* 43, 267–273. doi: 10.1111/cch.12404

Li, J., Diao, Y. C., Sun, M. M., and Pan, W. (2019). A study on the relationship between basic motor skills and physical fitness of 3∼5 year old children. *Sports Sci. Technol. China* 6, 52–58. doi: 10.16470/j.csst.2019017

Liu, C. S. (2014). *Experimental research on physical training of large class children*. M.A. thesis. HeBei: HeBei normal university.

Liu, C., Cao, Y., Zhang, Z., Gao, R., and Qu, G. (2023). Correlation of fundamental movement skills with health-related fitness elements in children and adolescents: A systematic review. *Front. Public Health* 11:1129258. doi: 10.3389/fpubh.2023.1129258

Liu, L. (2016). *Experimental research on improving physical fitness of primary school students by means of physical exercise function training*. M.A. thesis. Beijing: Capital Institute of Physical Education.

Liu, T. (2018). *Experimental research on the physical fitness development of preschool children through gross movement exercises*. M.A. thesis. Beijing: Beijing Sport University.

Logan, S. W., Robinson, L. E., Wilson, A. E., and Lucas, W. A. (2012). Getting the fundamentals of movement: A meta-analysis of the effectiveness of motor skill interventions in children. *Child Care Health Dev.* 38, 305–315. doi: 10.1111/j.1365-2214.2011.01307.x

Lopes, L., Póvoas, S., Mota, J., Okely, A. D., Coelho-E-Silva, M. J., Cliff, D. P., et al. (2017). Flexibility is associated with motor competence in schoolchildren. *Scand. J. Med. Sci. Sports* 27, 1806–1813. doi: 10.1111/sms.12789

Lopes, L., Santos, R., Pereira, B., and Lopes, V. P. (2013). Associations between gross motor coordination and academic achievement in elementary school children. *Hum. Move. Sci.* 32, 9–20. doi: 10.1016/j.humov.2012.05.005

Loukia, K., and Dimitris, C. (2022). A Greek traditional dance program for improving balance of young children. *Res. Dance Educ.* 188, 1381–1391. doi: 10.1080/03004430.2016.1261337

Ma, R., and Song, H. (2017). Impact of basic motor skill development on children's physical activity and health. *Sports Sci.* 4, 54–61+97. doi: 10.16469/j.css.201704007

Malina, R. M., and Katzmarzyk, P. T. (2006). Physical activity and fitness in an international growth standard for preadolescent and adolescent children. *Food Nutr. Bull.* 27, S295–S313. doi: 10.1177/15648265060274S511

Ministry of Education (2022). *Guidelines for quality assessment of kindergarten nursing education*. Available online at: https://www-moe-gov-cn.webvpn.sdjzu.edu.cn/srcsite/A06/s3327/202202/t20220214_599198.html (accessed November 20, 2023).

Mintjens, S., Menting, M. D., Daams, J. G., van Poppel, M. N. M., Roseboom, T. J., and Gemke, R. J. B. J. (2018). Cardiorespiratory fitness in childhood and adolescence affects future cardiovascular risk factors: A systematic review of longitudinal studies. *Sports Med.* 48, 2577–2605. doi: 10.1007/s40279-018-0974-5

Moliner-Urdiales, D., Ruiz, J. R., Ortega, F. B., Jiménez-Pavón, D., Vicente-Rodriguez, G., Rey-López, J. P., et al. (2010). Secular trends in health-related physical fitness in Spanish adolescents: The AVENA and HELENA studies. *J. Sci. Med. Sport* 13, 584–588. doi: 10.1016/j.jsams.2010.03.004

National Health Monitoring Centre (2022). *The fifth National physical monitoring bulletin*. Available online at: https://www.sport.gov.cn/n315/n329/c24335066/content.html (accessed November 10, 2023).

Niederer, I., Kriemler, S., Zahner, L., Bürgi, F., Ebenegger, V., Marques, P., et al. (2012). BMI group-related differences in physical fitness and physical activity in preschool-age children: A cross-sectional analysis. *Res. Q. Exerc. Sport* 83, 12–19. doi: 10.1080/02701367.2012.10599820

O'Brien, W., Belton, S., and Issautel, J. (2016). Fundamental movement skill proficiency amongst adolescent youth. *Phys. Educ. Sport Pedagogy* 21, 557–571. doi: 10.1080/02640414.2015.1096017

Okely, A. D., Booth, M. L., and Chey, T. (2004). Relationships between body composition and fundamental movement skills among children and adolescents. *Res. Q. Exerc. Sport* 75, 238–247. doi: 10.1080/02701367.2004.10609157

Pozuelo-Carrascosa, D. P., García-Hermoso, A., Álvarez-Bueno, C., Sánchez-López, M., and Martinez-Vizcaino, V. (2018). Effectiveness of school-based physical activity programmes on cardiorespiratory fitness in children: A meta-analysis of randomised controlled trials. *Br. J. Sports Med.* 52, 1234–1240. doi: 10.1136/bjsports-2017-097600

Pu, H. L., and Yang, D. (2017). An experimental study on the influence of "physical intelligence" and "fun track and field" courses on children's physical fitness. *J. Shenyang Inst. Phys. Educ.* 1, 124–128.

Qu, L. P. (2021). *Study on the construction of physical health promotion model and exercise intervention for Chinese adolescents*. Beijing: People's Sports Publishing House.

Riethmuller, A. M., Jones, R., and Okely, A. D. (2009). Efficacy of interventions to improve motor development in young children: A systematic review. *Pediatrics* 124, e782–e792. doi: 10.1542/peds.2009-0333

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., et al. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Med.* 45, 1273–1284. doi: 10.1007/s40279-015-0351-6

Roth, K., Kriemler, S., Lehmacher, W., Ruf, K. C., Graf, C., and Hebestreit, H. (2015). Effects of a physical activity intervention in preschool children. *Med. Sci. Sports Exerc.* 47, 2542–2551. doi: 10.1249/MSS.0000000000000703

Schott, N., Alof, V., Hultsch, D., and Meermann, D. (2007). Physical fitness in children with developmental coordination disorder. *Res. Q. Exerc. Sport* 78, 438–450. doi: 10.1080/02701367.2007.10599444

Shen, Y. Q., and Dan, F. (2023). Effects of soccer activities on physical and motor development of children aged 3-6: A meta-analysis based on 22 empirical studies in China. *J. Henan Univers. Sci. Technol.* 43, 70–77.

Sheng, Y., Liu, Y. H., Zhuang, J., and Chen, P. J. (2023). Physical activity abroad research progress of child and adolescent autonomy and enlightenment. *J. Shanghai Sports Inst.* 47, 83–91. doi: 10.16099/j

Shi, J. (2022). *Under the background of "Shuangjian" physical activity duration increased to the elementary student physical health impact study*. M.A. thesis. Yangzhou: Yangzhou University.

Smith, J. J., Eather, N., Morgan, P. J., Plotnikoff, R. C., Faigenbaum, A. D., and Lubans, D. R. (2014). The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. *Sports Med.* 44, 1209–1223. doi: 10.1007/s40279-014-0196-4

State General Administration of Sport (2015). *2014 National physical monitoring bulletin*. Available online at: https://www.sport.gov.cn/n315/n329/c216784/content.html (accessed November 11, 2023).

Tao, F. B., Wu, L. J., and Ma, J. (2017). *Child and adolescent health*. Beijing: People's Medical Publishing House.

Thelen, E. (1995). A dynamic systems approach to the development of cognition and action. *J. Cogn. Neurosci.* 7, 512–514. doi: 10.1162/jocn.1995.7.4.512

Thomas, J., Martin, P., and Etnier, J. (2022). *Research methods in physical activity*. Champaign, IL: Human Kinetics.

Tomkinson, G. R. (2007). Global changes in anaerobic fitness test performance of children and adolescents (1958-2003). *Scand. J. Med. Sci. Sports* 17, 497–507. doi: 10.1111/j.1600-0838.2006.00569.x

Tremblay, M. S., Shields, M., Laviolette, M., Craig, C. L., Janssen, I., and Connor Gorber, S. (2010). Fitness of Canadian children and youth: Results from the 2007-2009 Canadian health measures survey. *Health Rep.* 21, 7–20.

Ulrich, D. A. (2000). *Test of gross motor development*, 2nd Edn. Austin, TX: Pro-Ed.

Utesch, T., Bardid, F., Büsch, D., and Strauss, B. (2019). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Med.* 49, 541–551. doi: 10.1007/s40279-019-01068-y

Venetsanou, F., and Kambas, A. (2010). Environmental factors affecting preschoolers' motor development. *Early Child. Educ. J.* 37, 319–327. doi: 40.5687/36.10.10

Wang, F. (2021). *A study on the influence of Gross movement course intervention on the physical fitness of 4-5 year old children*. M.A. thesis. Shanghai: Shanghai University of Sport.

Wang, F. B. H., Li, Y. Q., Guo, X. D., and Feng, Q. (2021). Sedentary time, physical activity and abnormal body posture in adolescents. *China Youth Res.* 6, 5–12. doi: 10.19633/j

Wang, H., Hu, S., Li, Y. C., and Zheng, Y. (2019). Typical correlation between motor skills and physical fitness of preschool children. *Sports Sci. Technol. China* 6, 46–51. doi: 10.16470/j.csst.2019018

Wang, J., Cao, L., Xie, P., and Wang, J. (2018). Recreational football training improved health-related physical fitness in 9- to 10-year-old boys. *J. Sports Med. Phys. Fitness* 58, 326–331. doi: 10.23736/S0022-4707.16.06620-2

Wang, T. T. (2022). A study on the developmental characteristics and mechanism of physical activity, physical fitness and motor skills in preschool children. *Chin. Sports Sci. Technol.* 8, 49–61. doi: 10.16470/j.csst.2020068

Wang, X., Qin, J., Yang, T., Chen, S. Q., and Ding, H. X. (2020). An empirical study on the development of gross motor in 4～5 year old children promoted by multiple physical activity module. *J. Xian Sports Inst.* 4, 480–487. doi: 10.16063/j

Wang, Y. (2020). *An experimental study on the influence of functional training on the physical fitness of 9-10 year old male students*. M.A. thesis. Nanjing: Nanjing Normal University.

Wei, L. S., and Wei, Y. (2016). Functional training on physical development of children aged 9～10 years. *Youth Sports* 9, 96–98.

World Health Organization (2023). Global report on children with developmental disabilities. World Health Organization: Geneva

Wright, M. D., Portas, M. D., Evans, V. J., and Weston, M. (2015). The effectiveness of 4 weeks of fundamental movement training on functional movement screen and physiological performance in physically active children. *J. Strength Condition. Res.* 29, 254–261. doi: 10.1519/JSC.0000000000000602

Wu, C. H., Liang, C., Song, Z. P., and Xu, X. (2023). Meta-analysis of the effect of physical activity intervention on children's basic motor skills development. *J. Wuhan Sports Coll.* 8, 62–69.

Wu, C., Xu, Y., Chen, Z., Cao, Y., Yu, K., and Huang, C. (2021). The effect of intensity, frequency, duration and volume of physical activity in children and adolescents on skeletal muscle fitness: A systematic review and meta-analysis of randomized controlled trials. *Int. J. Environ. Res. Public Health* 18:9640. doi: 10.3390/ijerph18189640

Wu, J., Xiang, J. W., and Yuan, S. (2018). Changes of explosive quality development sensitive period of children and adolescents in China from 1985 to 2010. *Chin. Sch. Health* 39, 1132–1134. doi: 10.16835/j.cnki.1000-9817.2018.08.004

Wu, S. K., Zhang, S. W., and Xing, X. J. (2014). An international comparative study on learning goals in children's physical education and health from the perspective of motor development. *J. Chengdu Phys. Educ. Univers.* 5, 75–80.

Wu, Y. L. (2015). *An experimental study of functional motor training intervention on children's physical development*. M.A. thesis. Beijing: Capital Institute of Physical Education.

Xia, S. J. (2020). *Study on the influence of physical motor function Training on the physical fitness of 4-5 year old children in Shenzhen City*. M.A. thesis. Shenzhen: Shenzhen University.

Xin, F., Cai, Y. J., Bao, R., Wang, K., Chen, S. T., Liu, Y., et al. (2019). A systematic review of intervention studies on basic motor skills of children abroad. *Sports Sci.* 39, 83–97. doi: 10.16469/j.css.201902009

Xu, Q. P., Wang, X. Z., Ulrich Dale, A., Li, X., and Lu, Y. (2023). International comparison of basic motor skills development of children aged 3～10. *J. Shenyang Inst. Phys. Educ.* 6, 30–37.

Xu, Y. (2021). A study on the correlation between functional play and children's physical fitness development. *Sport. Goods Technol.* 4, 51–53.

Yang, M. L., Xu, X. Q., Ma, X. M., Lou, X. M., Wang, J. J., Yan, G. L., et al. (2022). Physical fitness status of primary and secondary school students in Henan province and analysis of related factors. *Sch. Health China* 43, 1873–1875.

Zhang, Y. T., Ma, S. X., Chen, C., and Liu, S. J. (2017). Physical activity guide for children and adolescents in China. *Chin. J. Evid. Based Pediatr.* 6, 401–409.

Zhao, M. L. (2020). Effects of two training interventions on physical fitness and different cognitive tasks of preschool children. *J. Beijing Sport Univers.* 5, 89–97. doi: 10.19582/j

Zheng, L. M. (2022). *Study on the effect of intervention in the teaching of basic motor skills of 3-6 year old children*. M.A. thesis. Jilin: Jilin Institute of Physical Education.

Zheng, Y., Ye, W., Korivi, M., Liu, Y., and Hong, F. (2022). Gender differences in fundamental motor skills proficiency in children aged 3-6 years: A systematic review and meta-analysis. *Int. J. Environ. Res. Public Health* 19:8318. doi: 10.3390/ijerph19148318

Zhou, J. X. (2020). Under the different levels of action perspective on the child's physical quality and BMI characteristics research. *Chin. Sports Technol.* 56, 62–68. doi: 10.16470/j.csst.2019174

Zhou, L. F., Cui, J., Zhang, X. J., Chen, H. Y., Jia, Y. H., Wu, Y. P., et al. (2021). Effects of physical motor function training on physical fitness and cognitive function in children aged 4-5 years. *Chin. Sch. Health* 6, 883–886+892.

Zhou, S. Q. (2022). *Feasibility study on the development of integrated program for the development of Basic Motor skills and physical fitness of 4-5 years old children*. M.A. thesis. Beijing: Capital Institute of Physical Education and Sports.

Zhou, X. H. (2010). Thinking on the concept of physical fitness and related problems. *Sports Cult. Guide* 6, 106–108+116.

Zou, G. N. (2016). *The functional fitness training for primary school grade five students to study the impacts of sports quality*. M.A. thesis. Hebei: Hebei normal university.