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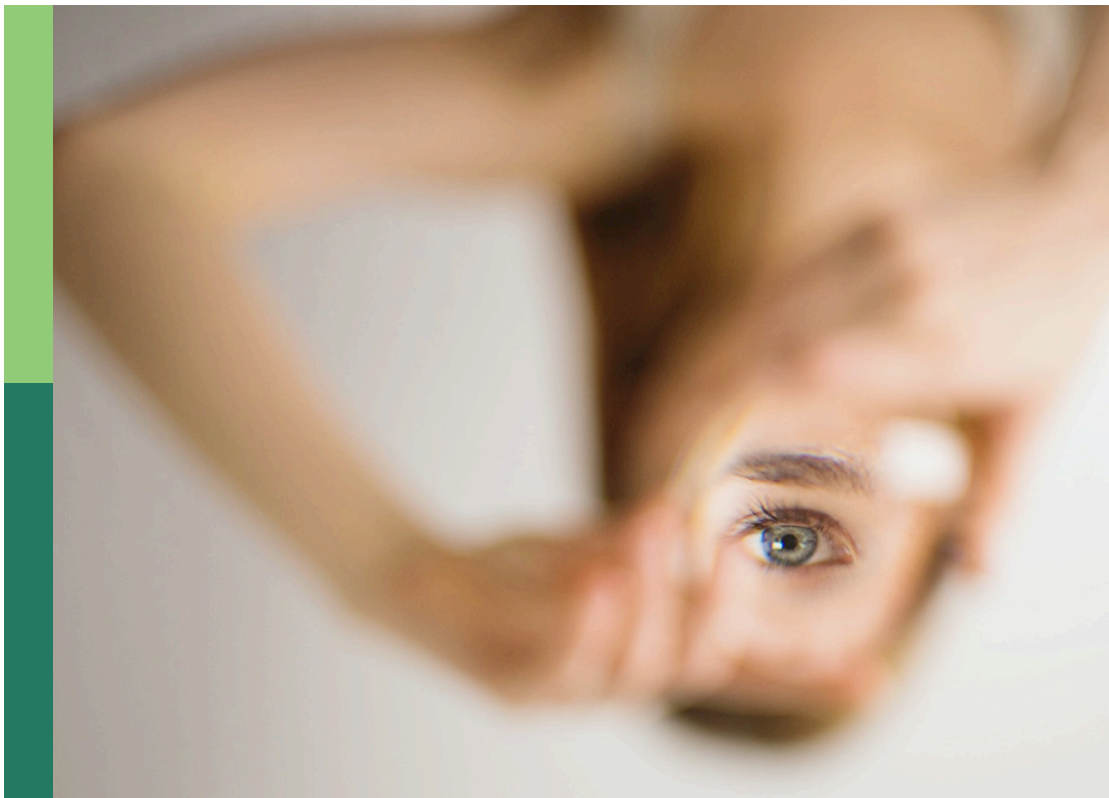

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Physical education, health and education innovation, volume II

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Editorial: Physical education, health and education innovation, volume II

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

Contemporary society demands the training of children and adolescents in environments that promote respect and educational values. That being said, educating children and adolescents extends beyond the mere transmission of academic content. It involves fostering individuals who are healthy, responsible, and prepared to face life's challenges. This requires an educational environment grounded in respect, human values, and practices that promote physical, mental, and social well-being. In this context, Physical Education (PE) emerges as a pivotal discipline in promoting healthy habits, encompassing regular physical activity, proper nutrition, and the reduction of sedentary behavior.

The World Health Organization (WHO) warns of the high rates of overweight and obesity, urging immediate action. In fact, the WHO has highlighted the concerning rates of overweight and obesity among young people in various countries, emphasizing the need for preventive actions starting from the early stages of schooling. Formal education, especially Physical Education, plays a crucial role in improving healthy habits through educational programs. Since the 20th century, studies have increased in educational centers and sports schools, not only promoting physical activity but also seeking to generate long-term adherence among students and athletes. This second volume of the Research Topic *Physical Education, Health and Education Innovation* includes contributions that highlight innovative programs promoting healthy habits related to physical activity, nutrition, and mental well-being in formal education, including primary, secondary, and university students. As said, schools, as significant social institutions, play a leading role in combating these issues, particularly through educational programs integrated into PE classes. Recent research indicates that as students progress through the educational system, especially in Secondary Education, there is a tendency to decrease physical activity and increase behaviors detrimental to health, such as alcohol and tobacco use, poor nutrition, and sedentary lifestyles. Therefore, PE should not be limited to encouraging occasional sports practice but should aim to develop continuous adherence to physical activity and sport throughout students' lives. Innovative interventions, such as that proposed by Deng et al., involving complex exercises like fancy rope-skipping, have demonstrated benefits not only in motor coordination but also in developing cognitive skills like selective attention and concentration. Incorporating

such practices into the school curriculum can be an effective and accessible strategy to enhance students' holistic development.

Another critical aspect related to physical activity is its contribution to mental health and social interaction within the school environment. Research by Galán-Arroyo et al., shows that physical self-efficacy—the perception of one's motor competence—can act as a protective factor against bullying. Students who feel physically capable tend to exhibit greater self-confidence and social skills, reducing their vulnerability to situations of violence or exclusion.

In this regard, PE also becomes a privileged space for developing pro-social values such as empathy, cooperation, and respect for diversity. Ongoing teacher training, as discussed by Hernández-González et al., should include inclusive pedagogical strategies capable of meeting the needs of all students, including students with disabilities, fostering an inclusive and equitable school environment.

Interventions conducted in Primary Education, such as the study by Gallotta et al., reinforce the importance of balancing study time with moments of movement and physical stimulation. Simple and playful activities, like rope skipping, have shown positive effects on motor coordination and attention in children aged 7–9 years. Similarly, Urbano-Mairena et al., highlight the benefits of active breaks during lessons, which can significantly increase physical activity levels without compromising academic performance. Moreover, a positive effect has also been reported as a result of approaches that combine sport and learning to promote the healthy development of adolescents with intellectual disabilities. The study by Wang et al., shows that a Badminton 'Body-Smart Integration' intervention can improve the cognitive ability of students with intellectual disabilities, with the latter showing a significant improvement in cognitive ability compared to students in the badminton group and the control group.

Beyond childhood, the implementation of physical activity programs has also proven effective in reducing screen time among university students, as observed by Özkara et al. Encouraging participation in active leisure activities contributes to a healthier and more balanced routine. Although often seen as a culprit in promoting sedentary behavior, technology, when well applied, can be an ally in the educational process. Cui et al., identified a positive relationship between the use of digital technologies and students' physical outcomes, provided there is genuine engagement with the proposed activities. In this case, engagement serves as a key mediator for the success of technological interventions.

Zhao and Ji, on the other hand, explored the use of virtual reality in teaching sailing and showed that this technology can significantly enhance students' intrinsic motivation and learning compared to traditional methods. This approach appears promising, especially in contexts where practical teaching faces structural limitations.

In the sports field, the coach plays a central role in the development of young athletes. Studies like that of Liu et al., reveal that individualized strategies, combining physical and psychological aspects, are essential for guiding athletes toward healthy and sustainable choices.

However, the competitive environment can sometimes favour a culture of harmful perfectionism. Meng et al., discuss how this personality trait, coupled with intense external demands, can jeopardize athletes' performance and well-being. However, when well mediated, this same climate can be transformed into a positive challenge. It is up to the coach to promote a motivational environment that values effort, personal achievement and teamwork, helping to strengthen the athletes' psychological capital and self-efficacy. Finally, promoting healthy habits and an active lifestyle should be a central priority in educational policies. Physical Education, when integrated into an innovative, inclusive pedagogical proposal based on scientific evidence, proves to be a powerful ally in the formation of autonomous, healthy individuals who are prepared for life in society. It is essential that schools, families, communities and public policy makers work together to build educational programmes that combine physical activity, nutrition and mental well-being. Only with an integrated and committed approach will it be possible to reverse the current trends of sedentary lifestyles and illness among children and adolescents. As we look to the future of education, it is clear that the health and well-being of students must be placed at the centre in the classroom—not as peripheral issues, but as the foundations for academic success and for building a more balanced and just society.

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The successful experience of gymnastics world champion coach: an interview analysis

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Objectives: The role of a coach in enhancing athletes' performance and achieving success is well-documented across numerous studies. However, the strategies employed by Chinese coaches in developing world champion gymnasts remain under explored.

Methods: This research involved a single case study focusing on a coach from the Chinese National Men's Gymnastics Team, credited with nurturing eight world champion gymnasts.

Results: The inductive content analysis leads to that 6 subthemes, "international perspective and collaborative ability," "ability to control and regulate training loads," "identifying athletes' needs and transforming them into motivation," "goal setting aligned with athletes' abilities," "adopting authoritative democratic coaching style," and "establishing hierarchical-style friendship", and 3 themes, "training management and planning," "motivation and goal setting," and "interpersonal communication" are manifested. An overarching theme "the successful experience of gymnastics world champion coach," is derived from the analysis.

Conclusion: This research bridges the gap between theoretical knowledge and practical application, offering valuable insights into the successful experiences of gymnastics world champion coaches. The findings have the potential to influence coaching methodologies globally, fostering the development of resilient, motivated, and high-performing athletes. Future research should focus on sport-specific studies, longitudinal analyses, and cross-cultural comparisons to further advance the field of sports coaching and validate the effectiveness of these innovative coaching strategies.

KEYWORDS

gymnastic, world champion, Olympic champion, coaching success, coaching methodologies

1 Introduction

The success of Olympic champion coaches is a testament to their multidimensional, integrated, and individualized approach, with psychological factors playing a paramount role. Interpersonal support, particularly from coaches, is crucial (Gould et al., 2002; Nash and Sproule, 2009; Breeman et al., 2014; Burns et al., 2018). Coaching facilitates the development

of cognitive, affective, and learning capabilities, aimed at fulfilling personal and organizational objectives (Berg, 2006). It is essential for coaches to understand the team's requirements and the motivational preferences of its members, applying suitable coaching methods within a supportive, transparent, and collaborative framework (Weinberg and Gould, 2015).

Effective leadership in coaching, adaptable to varying individual and situational contexts, is vital for motivating athletes toward success. This includes cultivating a productive coach-athlete relationship, enhancing motivation, and facilitating the achievement of team objectives (Kim and Cruz, 2016). Researchers have investigated the influence of coaching on superior athletic performance from two primary theoretical angles: coaching style and the coach-athlete relationship.

At the core, a successful coach assists individuals in achieving their personal and professional goals. By providing insights, tools, and techniques tailored to each person's unique challenges, success coaches bring clarity and direction. They support athletes at every step, whether it be in business success, relationship success, financial success, or more (Gilbert and Trudel, 2004).

When coaches watch our athletes compete as the best in the world at the Olympics, we are proud of what we as a country cultivate. However, Olympic coaches, though often less visible, play an indispensable role. While defining what it means to be an effective coach is challenging and controversial, most agree that reaching the Olympic coaching level is the pinnacle of one's sport.

What sets these coaches apart, making them the best in the world and leaders in their fields? There is a notable lack of research on successful coaching experiences in China, highlighting a need for enrichment in coaching theory. This study aims to contribute to the global academic community by examining the experiences of gymnastics Olympic champion coaches within the Chinese context. Additionally, this study employs interview research, based on content spanning 2 years, allowing for a deeper exploration of cultural characteristics.

1.1 The perspective of coaching style

There are two primary coaching styles: democratic and autocratic. The democratic approach focuses on empowering athletes to set their own goals, training objectives, and game strategies, whereas the autocratic style underscores authority and unilateral decision-making. Additionally, the concept of servant leadership has gained attention in recent years. Research has extensively explored the impact of these coaching styles on athlete outcomes.

In individual sports like table tennis, democratic coaching behaviors have been linked to better coping mechanisms and emotional outcomes (González-García and Martinent, 2020). Rune et al. (2008) observed that athletes in adverse situations show a preference for democratic behaviors and social support more than in successful situations, suggesting that challenging scenarios might enhance players' preference for a coaching style marked by significant task and relationship-oriented behaviors. Specifically, during periods of failure, players lean toward desiring more instructional and training-focused coaching, which directly contributes to task-oriented skill development. This approach has been recognized by elite athletes as crucial for improving performance and increasing the chances of success. Moreover, Rieke et al. (2008) introduced the concept of servant leadership in sports as a new paradigm for effective coaching, providing Christian sports coaches with a practical framework for their duties and responsibilities toward athletes and teams in a competitive environment (Vinson and Parker, 2021). According to Rieke et al. (2008), coaches who embrace servant leadership tend to foster athletes with healthier psychological profiles who also exhibit strong performance. However, in team sports, González-García et al. (2022) discovered that democratic coaching negatively impacts team task integration, while authoritarian coaching slightly improves social integration during competitions. Furthermore, mature and male athletes often prefer well-organized coaches with decisive decision-making skills, traits typically associated with autocratic coaching, as these athletes usually approach their sport with a higher degree of seriousness and view it as a structured organization (Breeman et al., 2014). Nevertheless, Woods et al. (2022) caution that an authoritative coaching style can lead to athlete burnout and psychological strain. Coaches adapt their leadership styles in response to specific circumstances. Throughout an athletic season, the dynamics of a coach's role and interactions with athletes evolve, influencing factors such as individual win-loss records, team performance in dual and tournament competitions, practice intensity, the caliber of recent opponents, outcomes against formidable or weaker opponents, coaching tenure, and overall satisfaction with teammates, sport, and coaching. These elements collectively shape the leadership approaches employed by coaches (Turman, 2001).

1.2 The coach-athlete relationship

Both the coach's and athlete's behavior will influence each other's perceptions and motivation levels (Jackson and Beauchamp, 2010; West, 2016). So, research involving coaches and athletes across various disciplines, competitive levels, and countries highlights the pivotal role of coach-athlete relationship quality in leadership and performance outcomes. Seiler (2006) identified this relationship as a critical determinant of competitive success. Kuhlin et al. (2019) analyzed 14 years of collaboration in figure skating, underscoring the influence of coach-athlete interactions on personal growth and career development. Drawing from foundational studies by Iso-Abola (1995) and Kelley et al. (1983), Jowett and colleagues emphasized the significance of these relationships in athletic performance and developed a comprehensive theoretical framework. This included the introduction of the 3C model (complementarity, co-orientation, closeness; Jowett and Meek, 2000, a coach-athlete relationship scale, and an integrated model linking relationship quality to individual and team performance (Jowett, 2007). Further, Jowett and Palmer (2010) demonstrated through surveys that negative aspects of the coach-athlete relationship, such as conditional or absent respect, can significantly impede athletic development and success by eroding trust, motivation, and performance (Mchenry et al., 2020). Additionally, research by Davis et al. (2021) and Ye et al. (2016) explored the mediating effects of interpersonal relationships on competitive outcomes within dyads. Minjung et al. (2018) advocated for a shift from a directive to a supportive coaching approach to foster these crucial relationships.

1.3 The aim of the current study

This study aims to explore a consistent coaching philosophy and approach of a distinguished Chinese coach through a case study, addressing the following reasons: Firstly, existing literature and theoretical frameworks exhibit limitations in thoroughly explaining the coaching philosophies of Chinese coaches, particularly within the context of China. Previous research has explored the effects of various coaching styles, such as democratic, servant, and authoritative, on athlete success. However, Chinese coaches often face the challenge of melding the seemingly contradictory styles of authority and democracy, a necessity arising from the unique structure of Chinese sports, where coaches are state-funded professionals rather than being privately hired by athletes. This setup mandates coaches to devise training strategies and objectives tailored to team needs, offering limited flexibility for athlete input, especially in areas aiming to improve professional competence and competitive experience. Additionally, the increasing focus on athletes' physical and mental health in China necessitates a shift toward a more democratic coaching approach. Contrarily, elite athletes with international accolades may enjoy enhanced negotiation leverage, diverging from the predominant servant-style coaching observed in Western contexts. Furthermore, the authoritative 3C model of the coach-athlete relationship (Jowett and Meek, 2000), deeply ingrained in Chinese Confucian values, does not advocate for athlete subservience, suggesting that this model may not fully capture the essence of Chinese coaching philosophies. Previous research has predominantly utilized surveys to investigate the relationships among various factors, yet it has not adequately captured the nuanced experiences of coaches in cultivating world champions. These experiences are distinct and highly individualized. The efficacy of sustaining successful coaching practices over prolonged training periods varies, with coaching approaches often reflecting unique personal attributes. Consequently, interviewing elite coaches is essential to uncovering effective coaching philosophies and methods. While empirical insights derived from structured experiments are invaluable, qualitative insights can significantly complement these findings and deepen our understanding of sports performance (Greenwood et al., 2012). Furthermore, coaches play multifaceted roles, including planning, observing, and providing feedback (Kidman and Hanrahan, 2011). It is noteworthy that most prior studies have focused on specific coaching traits linked to athletic success through singular methodologies or theoretical frameworks, neglecting a comprehensive evaluation of the coaching strategies or qualities of champions. Given the limitations of existing measurement tools in capturing the full spectrum of coaching attributes, conducting interviews with coaches proficient in athlete support can reveal new and critical aspects of coaching effectiveness (Gould et al., 2002).

2 Methods

2.1 Participants

Qualitative research, as Creswell (2014) advocates, prioritizes the careful selection of participants to achieve a comprehensive understanding of the research problem and associated inquiries. The likelihood of success tends to increase with a coach's experience, successful coaches often maintain their positions longer (Filho and Rettig, 2018). Thus, focusing on experienced and successful coaches is essential for this study. We chose to examine the coaching journey of Wang Guoqing, a distinguished coach at the Gymnastics Center of the General Administration of Sport of China, who boasts 20 years of coaching experience and has secured 8 gold medals in significant international competitions. Wang Guoqing, who holds a Doctorate in Sports Education from Beijing Sport University and is a second-level professor, brings a wealth of insight from his extensive career and demonstrates exceptional communication skills, essential for elucidating complex ideas and capturing critical information for this research.

Given the esteemed standing of our participant in Chinese Competitive Gymnastics and the in-depth nature of this case study, he consented to forego anonymity. This choice aligns with Wang's philosophy of sharing knowledge, as evidenced in an early exchange of communication: "*I think sharing is the key to progress. Coaches are a philosophy or art of interacting with athletes. If we do not express our opinions, we will not be able to gain support or even doubt, and we will stop moving forward. The Olympic spirit has recently brought up the concept of greater unity, which I believe is also a strengthening of human understanding of competitive sports and the emphasis on communication between people. Coaching also requires a greater emphasis on exploring the best coaching methods with an open attitude toward the outside world* (Wang Guoqing, personal communication, 1 January 2022)."

2.2 Interview guide

Through the synergistic collaboration of a seasoned PhD in psychology from Beijing Sport University and an assistant professor with a specialization in sports psychology from Xiamen University's Department of Physical Education, we have meticulously developed a semi-structured interview guide. This instrument is designed to explore the rich tapestry of world-class coaching success, with a keen focus on the competencies and collaborative dynamics between these coaches and their athletes. The guide is composed of a suite of open-ended questions crafted to elicit comprehensive responses that unveil profound insights. It has been subjected to a stringent review, meticulously examined by two distinguished coaches from the Chinese national team to ensure its pertinence and potency.

Following the execution of preliminary pilot interviews, which served as a trial run to assess the guidelines' practicality and lucidity, we implemented a series of minor yet impactful refinements to the phrasing of the questions within the guide. These enhancements were made with the intent to sharpen the instrument's precision and to catalyze a more profound and granular investigation into the lived experiences and viewpoints of our interviewees.

2.3 Data collection techniques

The data collection lasted for 2 years and 2 months. In order to comprehensively understand the interaction and coaching experience between Coach Wang (co-author of this study) and athletes, we continuously collected information through a combination of

online and offline methods throughout the entire process. Initially, in order to gain a rough understanding of the interaction between Wang and the athletes, as well as the characteristics of his coaching, we developed an interview outline and the questions to be asked. Written informed consent from the coach has been obtained during the interview. In addition, these work hours span a long time because Coach Wang happens to have high-intensity training tasks, and he is unable to allocate a fixed amount of time, each lasting at least an hour or more, to share his coaching experience with the main author on the national gymnastics team. The information we obtain each time is very limited. It was not until February to March 2024 that Wang had more time to share his successful coaching experience with us. Therefore, we conducted targeted semi-structured interviews with Coach Wang. The main interview content includes: (1) What ability do you think you have to cultivate so many world-class champions? (2) What kind of interpersonal relationship do you think you have established with Olympic champions?

2.4 Data processing and analysis

Data analysis is conducted using the manifest qualitative content analysis approach, as outlined by Robson (2011, p. 469). The transcribed data is carefully reviewed multiple times to ensure a thorough understanding of its entirety. Using thematic coding techniques, we categorize and label the data to reflect relevant concepts. Codes that are similar or related then combines into distinct themes. The following sections outline the primary themes extract from the qualitative dataset, as originally presented by Currie and Oates-Wilding (2012). In line with the study's objectives, theme, subtheme, and codes were inductively abstracted and condensed, focusing on the manifest content. Rigorous measures were taken to ensure that the categories exhibited internal homogeneity and external heterogeneity. The analysis was carefully executed by three of the authors, initially performed independently, followed by a collaborative discussion. The analytical process was iterative, characterized by a continuous oscillation between the data as a whole and its individual components. Notably, the coaches did not provide any feedback on the outcomes of the data analysis. Table 1 presents a representative example of the analytical procedure employed.

2.5 Quality and rigor

Based on a previous article published in PSE (Qin et al., 2023), our method selection enhances the research quality within the framework of critical realism. We choose to demonstrate rigor through two main forms: rigorous reflection and rigorous methods. Strict reflection makes the transmission of research transparent, including the knowledge and theoretical foundation of researchers (Danermark et al., 2019). Through reflection, we acknowledge that our explanation is only a perspective, influenced by the participation of the national sports system and cooperation with elite athletes. A rigorous approach is achieved through genuine analysis and critical reflection from friends. In addition, we invited one national team athlete, one national team coach, and one psychology PhD to explain the main viewpoints and the reasons for their emergence in this study. The research results and process have been unanimously agreed upon.

3 Results

The inductive content analysis leads to that 6 subthemes ("international perspective and collaborative ability," "ability to control and regulate training loads," "identifying athletes' needs and transforming them into motivation," "goal setting aligned with athletes' abilities," "adopting authoritative democratic coaching style," and "establishing hierarchical-style friendship"), and 3 themes ("training management and planning," "motivation and goal setting," "interpersonal communication") are manifested (Table 1). An overarching theme "the successful experience of gymnastics world champion coach," is derived from the analysis.

3.1 Training management and planning

The successful experience of world champion coaches in gymnastics underscores the critical importance of training management and planning, which can be divided into two sub-themes: international perspective and collaborative ability, and the ability to control and regulate training load.

3.1.1 International perspective and collaborative ability

Our findings suggest that exemplary coaches should possess international perspective and collaborative ability, to be more specific, an international outlook, adopting advanced training methodologies and technologies through global exchanges and collaborations to bolster the team's international competitiveness. This aligns with the principles of the Olympic Charter and the International Council for Coaching Excellence (ICCE), both dedicated to fostering the growth and global interchange among coaches. These entities underscore the significance of an international perspective and a collaborative ethos among world-class coaches. Lyle (2002) and Gould and Maynard (2009) posit that to thrive in the ever-evolving international sports landscape, outstanding coaches must continually update their knowledge and skills. Thoroughly understand the evolving rules of international competition and ensure that the athletes and coaching teams' preparation aligns with global standards. Wang mentioned, "*I sometimes communicate changes in competition rules with Arturs Mituls, the chairman of the Men's Artistic Gymnastics Committee of the International Gymnastics Federation*" "*I also often learn advanced training techniques and concepts, and adjust my own training plan at once*." Wang also stressed, "*Gymnastics is developing, the difficulty is increasing, and the international rules are changing. If we do not keep up with the times, constantly learn, and improve ourselves, we will inevitably be eliminated by the tide of the times!*" For it is difficult to make progress without going abroad to exchange and accept more advanced training concepts and methods (Reade et al., 2008). If training methods and philosophies are not updated according to international trends, there is a risk of misunderstanding the rules, which could lead to tactical failures in competitions (Gould et al., 2002).

TABLE 1 The data analysis process.

Theme	Subtheme	Code
Training management and planning	International perspective and collaborative ability	Fully grasp the changes in international competition rules and ensure that the preparation work of athletes and coaching teams is consistent with international standards.
		It is difficult to make progress without going abroad to exchange and accept more advanced training concepts and methods
		Misunderstanding of rules leads to the failure of tactical arrangements in the competition
		Encourage and support athletes to participate in international competitions and tournaments to gain practical experience and improve their technical skills
		Pay attention to the latest developments in sports technology internationally, such as sports biomechanics, data analysis, psychological training, etc., and apply these technologies to the training of local athletes.
	Ability to control and regulate training loads	Gymnastics competitions have certain risks, and fatigue training poses safety risks
		Believe in the subjective feelings of athletes, and when they mention that they are tired, believe it.
		Always monitor the fatigue status of athletes.
Motivation and goal setting	Identifying athletes' needs and transforming them into motivation	Engage in in-depth conversations with athletes to understand their interests, goals, and concerns
		Observe the behavior of athletes during training and competition to identify their needs and reactions. Understand the unique needs and motivations of each athlete.
		Customize training plans and support strategies to meet their personal goals.
		As a coach, embody the essence of passion and commitment, exemplifying the process of transforming enthusiasm and aspirations into tangible act
	Goal setting aligned with athletes' abilities	Understand the skill level, physical condition, psychological state, as well as their strengths and weaknesses of athletes
		Ensure that the set goals are specific, measurable, achievable, relevant, and time bound
Interpersonal communication	Adopting authoritative democratic coaching style	Although we embody a father like strictness, it is crucial to remain approachable.
		To convey authority without succumbing to anger or arrogance, demonstrate your expertise and leadership with calmness and respect, ensuring that your authority is recognized without the need for outbursts or overt displays of power.
		Athlete's compliance with coaches
		The democratic coaching style and friendly dialog allow athletes to openly express their thoughts and feelings.
	Establish hierarchical-style friendship	Obey the Chinese father hierarchical system
		Open Communication
		Mutual Trust
		Flexible Encouragement

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3.1.2 Ability to control and regulate training loads

Our research indicates that the ability to control and regulate training loads is crucial for world-class coaches. Athletes participating in elite sports face high training loads and increasingly saturated competition schedules. The psychological and physiological fatigue caused by overtraining can lead to long-term poor performance (Smith, 2003). According to the International Olympic Committee, training load broadly includes rapid changes in training and competition loads, congested competition schedules, psychological load, and travel. Poor management of these factors is a major risk factor for injury (Soligard et al., 2016). This is especially true in gymnastics competitions, where inherent risks and fatigue during training pose significant safety concerns.

Our research also emphasizes that coaches should trust athletes' subjective feelings toward fatigue, even though existing studies have proposed objective methods for quantifying exercise load, for example, the "training impulse" (TRIMP) which is consists of exercise intensity and duration calculated using the heart rate reserve method (Banister, 1991). However, ideally, athletes and coaches should match their perception of training load to achieve optimal adaptation (Pind and Mäestu, 2018). So, we hold Believe in the subjective feelings of athletes, and when they mention that they are tired, believe it, and always monitor the fatigue status of athletes.

3.2 Motivation and goal setting

The successful experience of world champion coaches in gymnastics also underscores the critical importance of motivation and goal setting, which can be divided into two sub-themes: identifying athletes' needs and transforming them into motivation, and setting goals aligned with athletes' abilities.

3.2.1 Identifying athletes' needs and transforming them into motivation

Our research reveals that adept coaches excel in discerning and linking athletes' needs with their achievements, a key factor in engaging athletes and driving them toward their peak psychological and physiological states (Weinberg and Gould, 2015). This ability is rooted in the deliberate efforts of individuals to meet their needs (Cheng et al., 2023). Fulfilling athletes' needs, particularly when it enhances their competitive performance or leads to outstanding results, serves as a significant motivational force in both training and competition (Vallerand, 2007). It should be noted, however, that the aspiration for achievement often operates on a subconscious level (McClelland et al., 1953), which requires coaches to explore and inspire.

Therefore, we believe it is necessary to focus on two key aspects. First, establish high-quality coach-athlete relationships and engage in in-depth conversations with athletes to understand their interests, goals, and concerns (Jowett and Cockerill, 2003). Second, a study of interviews with elite coaches found that, before intervening in performance issues, coaches must establish and maintain trust with athletes and their support networks. This ensures athletes feel safe discussing performance concerns and receive consistent and supportive information (Williams et al., 2023).

Wang Guoqing explained, "Only by establishing a realistic and tangible vision for each athlete can we maximize their inner potential and motivation for training. In the early stages of athletic training, their vision might be at a lower level, such as obtaining material rewards. As they progress and win more competitions, their vision gradually shifts toward higher levels, such as winning respect, proving oneself, and self-actualization. Of course, the pursuit of fame, fortune, and material possessions still exists. In reality, various human needs coexist, but at different times, different needs take precedence, and people prioritize meeting their most pressing needs."

The concept outlined above is corroborated by Goldthorpe (1987), whose research into social mobility and class structure in the UK underscores the impact of economic foundations on various social strata, positing that economic standing significantly influences one's social status and interests.

On the other hand, as a coach, it is important to be a model of passion and commitment, demonstrating how to translate passion and goals into action. This approach is supported by many researchers (Martens, 2012; Whitmore, 2017).

3.2.2 Goal setting aligned with athletes' abilities

We find that skilled coaches can set goals based on the abilities of athletes, which can enable them to impart knowledge on skill development and prepare athletes to achieve optimal performance (Gould et al., 2002; Johnson et al., 2011; Kuma, 2019). It's also supported by Gearity and Murray (2011), they identify five themes from athletes' self-reports: inadequate coach instruction, indifference, unfairness, inhibition of athletes' psychological skills, and athlete coping. Two of these themes, inhibition of athletes' psychological skills and coping, are closely related to psychological structure and are discussed in this article. The theme of inhibiting athletes' psychological skills includes descriptions of poor coaching practices that can distract attention, generate self-doubt, weaken motivation, and divide the team. The theme of athlete coping describes how athletes manage and respond to poor coaching.

In addition, the present study finds that a great Olympic coach should ensure that the set goals are specific, measurable, achievable, relevant, and time bound. As scholars emphasize the importance of setting SMART goals to provide direction and focus for athletes (North et al., 2021).

3.3 Interpersonal communication

Interpersonal communication is vital for world-class coach including the ability adopting authoritative democratic coaching style and establishing hierarchical-style friendship.

3.3.1 Adopting authoritative democratic coaching style

Our research has found that using an authoritative democratic coaching style is an important coaching experience. The authoritative democratic coaching style is a hybrid approach to leadership that combines the assertiveness and clear direction of authoritative coaching with the inclusiveness and participatory nature of democratic coaching. In this style, the coach maintains a strong sense of authority and control, which serves as the foundation for fostering a collaborative and engaging environment.

In this coaching style, the coach sets clear goals and expectations for their team members, but also encourages open communication

and feedback. As Jones et al. (2019) note, this approach allows for a more collaborative environment where team members feel heard and valued. The coach listens to the opinions and suggestions of their team members and considers them when making decisions. They also provide guidance and support to help their team members develop their skills and achieve their goals.

This coaching style fosters a positive and collaborative team environment, where team members feel valued and respected. It promotes trust and accountability, as team members are encouraged to take responsibility for their actions and work together toward a common goal. Overall, the authoritative democratic coaching style is effective in creating a high-performing team that is motivated, engaged, and committed to achieving success (Jones et al., 2019).

In response to the question, "what kind of interpersonal relationship do you think you have established with Olympic champions?" Coach Wang in our study once replies: maintain a disciplined and approachable demeanor, similar to a father's image. To achieve self-reliance without anger. Subsequently, the researchers questioned whether this authority or authority would create a fear that would be detrimental to the success or mental health of athletes? Wang clarified, "Although we embody a father like strictness, it is crucial to remain approachable. The democratic coaching style and friendly dialog allow athletes to openly express their thoughts and feelings."

3.3.2 Establish hierarchical-style friendship which is a positive coach-athlete relationships

Our research indicates that elite coaches prioritize fostering positive coach-athlete relationships characterized by Obeying the Chinese father hierarchical system, open communication, mutual trust, and encouragement. These relationships are foundational to improved athletic performance (Weinberg and Gould, 2015). Jowett and Cockerill (2003) find that Olympic medalists consistently identified open communication, mutual trust, and encouragement as critical components in building positive coach-athlete relationships.

3.3.2.1 Obey the Chinese father hierarchical system

We find that great coaches need to maintain confidence and authority, otherwise it is difficult for athletes to trust them. The hierarchical structure within the Chinese national sport system significantly influences the behavior and compliance of athletes and coaches. This system, often referred to as the "Whole-Nation system," is characterized by its centralized structure, medal-oriented focus, and semi-closed environment (Ge et al., 2016). The legitimacy of coaches demanding obedience from athletes can be understood through several key points:

Centralized Structure and Medal Orientation: The centralized structure ensures athletes are trained under a unified methodology, crucial for high performance and winning medals. This system places immense pressure on athletes, with coaches playing a pivotal role in guiding them. The hierarchical nature necessitates a clear chain of command, where athletes follow coaches' directives to achieve collective goals (Ge et al., 2016).

Psychological Training and Sociocultural Meridians: Psychological training is deeply rooted in sociocultural meridians, including cultural inheritance and traditional beliefs such as "harmony with differences" and the balance between Confucianism and Taoism (Si et al., 2011). These elements emphasize respect for authority and hierarchical relationships, integral to the coach-athlete dynamic in China. Integrating these characteristics into training fosters discipline and respect, legitimizing coaches' authority.

Cultural and Psychological Integration: Integrating cultural and psychological factors into training is crucial for athletes' overall development. The hierarchical system, aligning with traditional Chinese values, provides a stable framework for growth. Coaches, by embodying these values and maintaining structure, help athletes navigate elite sports pressures and achieve their potential (Si et al., 2011).

In conclusion, the hierarchical system within the Chinese national sport system is both a cultural norm and a practical necessity for achieving excellence in sports. Coaches' demands for obedience are legitimized by the need for a centralized, disciplined, and culturally coherent training environment. This system ensures athletes are well-prepared to meet international competition challenges and achieve success on the global stage.

3.3.2.2 Open communication

Open communication is essential for preventing misunderstandings and conflicts due to insufficient communication. It facilitates the timely and effective resolution of issues arising during training and competition, thereby enhancing professional performance and promoting the personal growth of athletes. Moran and Megan (2010) even propose an innovative coaching approach that emphasizes the autonomy and professional development of coaches through four core practices: listening, expressing, designing, and supporting. They advocate for a faultless environment and strengths-based improvement, demonstrating the transformative power of dialog in educational improvement.

In China's competitive sports culture, even Olympic champions must respect the authority of their coaches, who hold significant dominance during training. However, elite athletes often have a clear understanding of their needs. As Olympic champion Xu Mengtao articulated, athletes can fully follow the coach's guidance from 0% to 99%, but to achieve the final 1% to reach 100%, athletes must understand their own strengths and weaknesses. They should communicate effectively with their coaches about their training programs, even suggesting amendments based on their insights. This perspective is supported by a comprehensive meta-analysis (Theeboom et al., 2014).

However, the traditional Chinese education system, rooted in Confucianism, emphasizes "respect for teachers and valuing their teachings." Teachers are seen not only as knowledge transmitters but also as moral guides. Students are expected to treat their teachers with utmost respect and diligently learn from them. In this cultural context, coaches are akin to teachers, enjoying absolute respect and generally holding the view that their authority should not be questioned. Coaches who practice open communication are rare. Most prefer to maintain their positions and perspectives, even when faced with challenges, and expect athletes to reflect on their own shortcomings rather than questioning the coach's methods.

Coach Wang's coaching philosophy commands respect and recognition, not only because he genuinely respects his players but also because he embraces their questioning. Wang states, "I will correct what my players say I really did wrong." His excellent communication skills enable him to address the team's issues promptly. Wang emphasizes the importance of communication, stating, "I think

it's very important to communicate with the athletes in my group. In addition to teaching them the essentials of movement in training, we often communicate with each player individually, allowing them to speak freely and respecting their opinions. For incorrect ideas and demands, I educate them through persuasion and guidance, and the effect is very good!" This approach has resulted in increased respect and trust from the players. By fostering an open dialog with his players, Wang has cultivated a strong sense of team cohesion and trust, solidifying the Chinese gymnastics team's status as the ace of China's sports corps.

3.3.2.3 Mutual trust

Mutual trust is the cornerstone of the coach-athlete relationship. Its supported by Schiemann et al. (2019) and Tiitu (2017). Trust enables coaches and athletes to collaboratively develop and adapt training programs to achieve optimal performance. For instance, the collaboration between renowned track and field coach Alberto Salazar and Olympic champion Mo Farah exemplifies a high level of mutual trust. During Farah's training, Salazar continuously adjusted the training intensity and methods based on Farah's feedback, ultimately contributing to Farah's outstanding achievements.

Unlike the traditional emphasis on high intensity and large training volumes to produce results, Coach Wang advocates for flexible training methods based on trust. He stated, "I always trust my athletes, and when they tell me they are not in good health and wish to reduce, modify, or even rest, I usually agree. Sometimes they voluntarily increase their training despite fatigue; in such cases, I insist that they rest to prevent injuries from overtraining. It has been proven that each time I support their adjustments and rest, they work harder and often exceed their previous training achievements."

With Coach Wang's trust, the athletes feel comfortable expressing themselves honestly, rather than lying to secure more vacation time. They are not only transparent about their rest needs but also proactively seek Coach Wang's advice on crucial decisions during training and competitions. This relationship of trust allows the players to fully embrace Coach Wang's guidance, enabling them to commit to their training without resistance.

This coach-athlete relationship, founded on mutual trust, not only enhanced the athletes' training outcomes but also strengthened team cohesion. Ultimately, this contributed to the improvement of the team's overall performance.

3.3.2.4 Flexible encouragement

Coach encouragement, as the primary form of social support, plays a critical role in promoting athlete success. The motivational model of the coach-athlete relationship emphasizes the importance of a coach's encouragement and support in enhancing athletes' motivation and performance. Encouragement not only boosts an athlete's confidence but also stimulates their potential (Gilbert and Trudel, 2004). Coaches must recognize even small improvements in their players (Gould et al., 2002). Former USA Gymnastics coach Bella Karolyi is known for his motivational training methods, which inspired athletes to strive for success in international events through constant encouragement and praise.

Coach Wang stated, "In my coaching process, consistent encouragement and praise are given throughout the training. Acknowledgement and affirmation are especially provided when athletes exhibit an indomitable spirit, courage, and resilience in the face of setbacks." Encouragement from the coach helps athletes to face challenges bravely and make progress. However, when an athlete achieves a major accomplishment and begins to show slackness, the coach should withhold encouragement and instead help the athlete adjust their mindset by motivating them to pursue higher goals. As Coach Wang said, "I usually give them the most praise and encouragement when they are facing challenges, and remind them to refrain from arrogance after they have succeeded."

This dynamically adapted encouragement strategy not only motivates athletes at critical moments but also keeps them grounded and humble as they achieve success and continue to pursue excellence. By establishing a coach-athlete relationship based on open communication, mutual trust, and continuous encouragement, it is possible to effectively enhance an athlete's overall performance and mental fitness.

4 Discussion

The study identifies three key themes in the successful experiences of gymnastics world champion coaches: "training management and planning," "motivation and goal setting," and "interpersonal communication." These themes are reflected in the following abilities: (1) "international perspective and collaborative ability," (2) "ability to control and regulate training loads," (3) "identifying athletes' needs and transforming them into motivation," and (4) "goal setting aligned with athletes' abilities." These aspects are validated by current research and contribute a new perspective to the existing body of knowledge. Additionally, the study introduces two innovative concepts: (5) "adopting an authoritative democratic coaching style" and (6) "establishing hierarchical-style friendships." These innovations provide a fresh perspective on the successful experiences of coaches, offering valuable insights into effective coaching practices to the world.

To be more specific,

(1) "International perspective and collaborative ability"

Currie and Oates-Wilding (2012) believe that knowledge of Sport and Focus on Needs of Athlete is one of the most vital factors Olympic coaches attribute to their success. So, coach Wang points out that actively participating in international competitions and learning about advanced technologies and their applications are essential experiences for a successful coach. For (1) participating in international competitions and tournaments will gain athletes' practical experience and improve their technical skills (Gould and Carson, 2008). (2) Stay attuned to the latest developments in international sports technology, including sports biomechanics, data analysis, and psychological training, especially in the era of digital sports transformation driven by AI, VR, AR, and DV (Gould and Maynard, 2009) and apply these technologies to the training of athletes, which is the top priority of future Olympic preparations (Cossich et al., 2023). Some scholars have proposed the trend of intelligent transformation of training methods based on the intelligent data analysis methods currently used in the field of intelligent sports training (Rajšp and Fister, 2020). For example, an increasing number of "sports vision training" practices rely on the idea that practicing high-demand visual perception, cognition, or eye movement tasks can enhance the ability to process

and respond to visual stimuli, thereby improving sports performance (Appelbaum and Erickson, 2016).

(2) "Ability to control and regulate training loads"

The ability to control and regulate training loads not only aids in preventing fatigue, thereby extending the competitive careers of athletes, but also enhances the efficiency of training sessions. Effective regulation of training loads necessitates that coaches possess a comprehensive understanding of athletes' perceptions of the imposed workload, the importance of sufficient rest, and the physiological changes stemming from consecutive training sessions (Impellizzeri et al., 2004; Buchheit et al., 2013).

As Wang mentioned, *"the fatigue of athletes in gymnastics is twofold—physical fatigue and psychological fatigue, which is different from other sports. In fact, most injuries of gymnasts are caused by fatigue, and in situations of abundant physical strength and good physical and mental state, they are less likely to be injured" "Physical fatigue is easy to recover from, while psychological fatigue is more challenging. In severe cases, even top athletes may not dare to perform difficult movements, and improper control of training volume can also lead to this situation."*

> *"Now our group has 6 team members, and there are 6 training plans with different training contents, which may be different from group sports. Usually, their training starts at the same time, but the end times often* vary. *One of my athlete's training characteristics are high intensity, short duration, and few but precise. And another one entered the training state slowly, so his intensity was arranged to be moderate, relatively long, and lukewarm. he often ended the training class last."*

(3) "Identifying athletes' needs and transforming them into motivation"

High intensity training is full of pressure and frustration, which requires strong mental motivation to complete. Need to be able to motivate and highly connect with personal needs. As Mageau and Vallerand (2003) proposed a motivational model for the coach-athlete relationship, emphasizing the role of communication and understanding in establishing effective relationships. Coaches must observe athletes' behavior during training and competition to identify their needs and reactions. Understanding the unique needs and motivations of each athlete is crucial. Wang Guoqing stated, "Honors, rewards, and benefits are the most effective motivators. I often ask athletes why they practice gymnastics, what their dreams are, or what they need the most. Then, I help athletes establish a vision map, showing what they can achieve once they succeed or win a championship." Furthermore, according to the self-determination theory, individuals are more motivated to pursue their goals when their basic needs are met, leading to greater focus and engagement (Deci and Ryan, 2000). This means that the satisfaction of needs and success are mutually reinforcing. According to Maslow's hierarchy of needs theory, the satisfaction of different levels of needs corresponds with success at different levels.

(4) "Goal setting aligned with athletes' abilities"

It's also supported by the scholars, the reason may be that, on the one hand, humans are purposeful agents who act to meet their needs. However, the human soul is a mosaic composed of multiple selves and conflicting needs. Scholars have proposed a psychological mechanism for resolving this conflict and contradiction, namely "goal persistence." "Goal persistence" refers to persisting in pursuing the original intention despite unexpected changes that may make the intention less ideal (Cheng et al., 2023). In addition, Locke and Latham (2002) summarize 35 years of empirical research on goal setting theory and found that emphasizing the importance of goal setting for individual effort and focus. On the other hand, Set goals based on athletes' competence is essential, for both self-efficacy theory and self-determination theory believe that when the difficulty of a task exceeds the level that an individual can achieve through effort, it is easy for the individual to lose confidence and motivation (Bandura et al., 1997; Deci and Ryan, 2000).

As stated by Wang, "*the setting of goals is very important, and I have divided them into three stages: short-term, medium-term, and long-term. However, tailored plans and goals tailored to each athlete's characteristics are the most crucial. The goals I set during training are not too high, and through hard work, they can achieve them. When they achieve the established goals, they have more confidence to challenge new goals. If the goal is set too high, it will be difficult for athletes to achieve it through hard work, which indicates that the plan formulated by the coach is wrong and unrealistic, and more importantly, it will undermine the confidence of the athletes.*"

Mastering these skills presents a formidable challenge, necessitating coaches to exhibit two essential qualities:

(5) "Adopting authoritative democratic coaching style"
(6) "Establishing hierarchical-style friendship"

For the first, the establishment of a hierarchical-style rapport is vital, enabling coaches to assert authority within the context of China's national structure and traditional values, akin to a paternal figure, contrasting with Western egalitarian norms. Second, implementing an authoritative democratic coaching approach is crucial, where coaches lead with confidence and authority while allowing athletes the liberty to voice their thoughts and feedback. This strategy aims to spur innovation, instill a sense of responsibility in team members, and foster collaborative achievement of shared objectives. As repeatedly highlighted by Wang, a champion coach's demeanor, while non-confrontational, should exude a natural, commanding presence that commands respect. This dual approach—hierarchical-style rapport and authoritative democratic coaching—enriches the dialog on coaching methodologies and the dynamics of coach-athlete interactions, offering fresh perspectives and strategies for international coaching research. The introduction of two concepts—authoritative democratic coaching and hierarchical-style friendship—is driven by several considerations. Firstly, champion coaches must possess decision-making authority, exhibiting strength and decisiveness, as highlighted by Wang, who emphasized the critical importance and influence of gymnastics in the Olympics. He argued that to secure a team championship, coaches must demonstrate boldness and authoritative leadership (Rune et al., 2008). Wang also noted the psychological dependence of gymnasts on their coaches, underscoring the necessity for a coach who commands respect and trust. He further posited that athletic performance is key to gaining team members' respect, and that authoritative leadership requires a range of supporting skills. Additionally, the study suggests that the adoption of an authoritative leadership style is shaped by China's national sports system and Confucian culture. Specifically, the structure of China's competitive sports, being a state system, differs fundamentally from

the market-driven model prevalent in the West. In China, coaches and athletes serve the nation's interests, with the government covering their salaries and coaches enjoying a status akin to government officials. This establishes a hierarchical dynamic with athletes, contrasting with the Western model where athletes may hire and dismiss coaches based on personal preference, leading to a more egalitarian coach-athlete relationship. Wang remarked that coaches, being employees of the General Administration of Sport of China, cannot adopt a servile approach. This distinction necessitates a balance between authority and rapport in coaching strategies.

Cultural distinctions significantly influence coaching approaches in Western countries and China. Western coaches tend to favor a more democratic style, emphasizing the importance of building relationships, valuing athletes' participation and autonomy for their motivation and development (Jowett, 2007; Becker, 2009), and leveraging personal experiences to derive insights (Côté and Sedgwick, 2003). This perspective views the coach's role as not merely instructive but as facilitators of athlete independence, decision-making involvement, and critical thinking skills (Côté and Gilbert, 2009). Conversely, Chinese coaching practices, deeply rooted in Confucian traditions, often embody a more paternalistic approach. Yao (2000) notes that Chinese coaches, guided by Confucian ethics, assume a fatherly role, expecting rigorous adherence from athletes, in line with the "Five Virtues" of societal expectations. Reflecting these cultural norms, Wang et al. (2014) adapt the coach-athlete relationship scale to include elements of athlete obedience. Wang further illustrates this dynamic by comparing his longstanding relationships with athletes to that with his own son, emphasizing the duration and depth of these connections. He argues that a top-tier gymnast typically remains with the same coach until retirement, underscoring the rarity of coach changes, except in cases of lesser skilled coaches. Frequent changes in coaching affiliations, Wang suggests, correlate with a higher likelihood of an athlete's premature exit from the sport, highlighting the stability provided by enduring coach-athlete partnerships in contributing to sustained success in gymnastics.

To make informed decisions and successfully steer athletes toward competitive excellence, coaches must continually gather information about athletes' physiological, psychological, and competitive conditions through engaging in democratic coaching practices and fostering open communication. Central to this approach is the establishment of positive, cooperative relationships characterized by transparent communication, mutual trust, and support. Specifically, a culture of openness, where individual self-expression leads to reciprocal sharing of personal experiences (Miller, 1990) lays the groundwork for building trust, enhancing understanding, and fostering a deep connection between athletes and coaches. This trust empowers athletes to fully embrace coaching guidance, thereby boosting their commitment and effort. Such relationships and effective communication not only strengthen team unity and collaboration but are also pivotal for the training success and overall performance of Olympic champions. Wang has highlighted *the significance of communication, noting that even highly skilled coaches may falter if they seldom engage with their team. A lack of open dialog can deter athletes from sharing vital insights about their physical and mental states, potentially leading to training approaches that ignore individual needs, thereby causing friction and, more critically, increasing the risk of injuries*. According to Knudson and Morrison (2002), a key responsibility for coaches is to clearly articulate necessary adjustments for performance enhancement. Clear communication enables athletes to understand coaching strategies and goals, amplifying their motivation and zeal for training. Moreover, effective communication among coaching staff fosters a collaborative environment, aligning objectives, providing precise feedback, and offering the support needed to navigate challenges and unlock potential (Fletcher and Arnold, 2011). Positive, collaborative relationships also play a crucial role in resolving conflicts, managing psychological challenges (Kavussanu et al., 2008), and addressing career-related concerns between coaches and athletes (Stambulova and Wylleman, 2019).

5 Strengths, limitations, practical application, and possible directions for future research

5.1 Strengths

Innovative Academic Perspectives: We introduced the concepts of "authoritative democratic coaching style" and "hierarchical-style friendship," enriching the discourse on coaching styles and coach-athlete relationship theories. This contribution offers fresh perspectives and methodologies for the field of international coaching research. In addition, following Hodgson et al.'s (2017) recommendation to concentrate on a singular sport, this study's exploration of gymnastic coaching offers specific environmental insights, minimizing the potential interference from other sports.

5.2 Limitations

Although the findings might be relevant to other Olympic disciplines, further sport-specific research is warranted. Reliance on Self-Reports: The study's sole dependence on coaches' self-reports introduces the risk of self-deception bias, as highlighted by Colbert et al. (2012). Future research should aim to corroborate and expand upon our results by incorporating observations from athletes, considering the relational and interpersonal nature of coaching.

5.3 Practical application

This study provides significant contributions to the field of sports coaching by identifying three key themes in the successful experiences of gymnastics world champion coaches: "training management and planning," "motivation and goal setting," and "interpersonal communication." These themes are further elucidated through the following abilities: "international perspective and collaborative ability," "ability to control and regulate training loads," "identifying athletes' needs and transforming them into motivation," and "goal setting aligned with athletes' abilities." These aspects are validated by current research, thereby enriching the existing body of knowledge with a new perspective.

Moreover, the study introduces two innovative concepts: "adopting an authoritative democratic coaching style" and "establishing hierarchical-style friendships." These novel insights provide a fresh perspective on the successful experiences of coaches, offering valuable

guidance for effective coaching practices. By integrating these innovative approaches, the study not only enhances our understanding of elite coaching strategies but also offers practical applications for coaches aiming to achieve excellence in their respective sports.

In summary, this research bridges the gap between theoretical knowledge and practical application, providing a comprehensive framework for understanding and implementing successful coaching practices. The findings have the potential to influence coaching methodologies globally, fostering the development of resilient, motivated, and high-performing athletes.

5.4 Possible directions for future research: future research directions

(1) Building on the strengths and addressing the limitations of this study, future research should focus on several key areas to further advance the field of sports coaching. (2) Sport-Specific Research: While this study provides valuable insights into gymnastics coaching, there is a need for sport-specific research across other Olympic disciplines. (3) Longitudinal Studies: Conducting longitudinal studies will allow researchers to track the long-term impact of coaching strategies on athlete performance and development. This will help in identifying which coaching practices are most effective over time and how they contribute to sustained athletic success. (4) Cross-Cultural Comparisons: Given the global nature of sports, it is essential to explore how different cultural contexts influence coaching practices and athlete responses. Cross-cultural studies can provide insights into the adaptability and effectiveness of the "authoritative democratic coaching style" and "hierarchical-style friendship" in various cultural settings.

6 Conclusion

The inductive content analysis of this study has identified six subthemes and three themes that encapsulate the successful experiences of gymnastics world champion coaches. The subthemes include "international perspective and collaborative ability," "ability to control and regulate training loads," "identifying athletes' needs and transforming them into motivation," "goal setting aligned with athletes' abilities," "adopting authoritative democratic coaching style," and "establishing hierarchical-style friendship." These subthemes are organized under the main themes of "training management and planning," "motivation and goal setting," and "interpersonal communication," all contributing to the overarching theme of "the successful experience of gymnastics world champion coach."

6.1 Training management and planning

The study underscores the critical importance of training management and planning, highlighting the need for an international perspective and collaborative ability, as well as the ability to control and regulate training loads. Coaches must stay abreast of global competitive sports trends and adapt advanced training methodologies to enhance their team's international competitiveness. Effective regulation of training loads is crucial to prevent fatigue and injuries, ensuring athletes' long-term performance and career longevity.

6.2 Motivation and goal setting

Successful coaches excel in identifying athletes' needs and transforming them into motivation. They establish high-quality coach-athlete relationships (Cook, 2019), engage in in-depth conversations to understand athletes' interests and goals, and set specific, measurable, achievable, relevant, and time-bound (SMART) goals aligned with athletes' abilities. This approach fosters a sense of purpose and direction, enhancing athletes' focus and engagement.

6.3 Interpersonal communication

Interpersonal communication is vital for world-class coaches, encompassing the adoption of an authoritative democratic coaching style and the establishment of hierarchical-style friendships. The authoritative democratic coaching style combines assertiveness with inclusiveness, fostering a collaborative and engaging environment. Establishing hierarchical-style friendships, characterized by open communication, mutual trust, and encouragement, is essential for building positive coach-athlete relationships.

The study introduces two innovative concepts: "adopting an authoritative democratic coaching style" and "establishing hierarchical-style friendships." These concepts provide fresh perspectives on effective coaching practices, emphasizing the importance of balancing authority with collaboration and fostering strong, trust-based relationships with athletes. By integrating these approaches, coaches can create a high-performing team environment that is motivated, engaged, and committed to achieving success.

In conclusion, this research bridges the gap between theoretical knowledge and practical application, offering valuable insights into the successful experiences of gymnastics world champion coaches. The findings have the potential to influence coaching methodologies globally, fostering the development of resilient, motivated, and high-performing athletes. Future research should focus on sport-specific studies, longitudinal analyses, and cross-cultural comparisons to further advance the field of sports coaching and validate the effectiveness of these innovative coaching strategies.

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 the Department of Physical Education, Xiamen 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. 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

XL: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. XW: Validation, Writing – review & editing, Formal analysis. HQ: Formal analysis, Writing – review & editing. SM: Formal analysis, Methodology, Supervision, Writing – review & editing, Validation, Resources. GW: Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization.

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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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Academic achievement and healthy lifestyle habits in primary school children: an interventional study

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Purposes: First, to examine the relationship between primary school children's academic achievement and healthy lifestyle habits. Second, to evaluate the effectiveness of two different 5-month physical education interventions (traditional physical education vs. coordinative physical education) on children's academic achievement. Third, to examine whether variations of anthropometric variables, fitness level, gross motor coordination, physical activity level, sedentary time, attentional performance, fruit and vegetable consumption, meal frequency and type of physical education intervention could predict children's academic achievement variations.

Methods: Before and after the intervention, Italian language and mathematics skills, anthropometric variables (weight, height, body fat percentage, BMI), physical fitness (aerobic fitness, muscular strength, flexibility), gross motor coordination, attentional performance (processing speed, concentration performance, performance accuracy, attentional and inhibitory control), physical activity level, sedentary time and eating habits (meal frequency, fruit and vegetable consumption) were assessed in 161 Italian primary school children, randomly assigned to a traditional physical education group or to a coordinative physical education group.

Results: Physical activity level, gross motor coordination and aerobic fitness moderately predicted mathematics skill ($R^2 = 17\%$). Moreover, physical activity level, aerobic fitness and muscular strength moderately predicted Italian language skill ($R^2 = 21\%$). Intervention type differently affected academic achievement. Specifically, Italian language and mathematics skills significantly improved only after traditional intervention. Fruit consumption increase was positively associated with the improvement in academic achievement. Coordinative physical education intervention was associated with a lower probability of improvement in Italian language and mathematical skills.

Conclusion: Motor ability and lifestyle habits may have a positive influence on academic achievement in children. Unexpectedly, traditional physical education intervention resulted to be more effective on both Italian language and mathematical skills.

KEYWORDS

attentional performance, eating habits, fitness level, motor coordination, physical education intervention, weight status

1 Introduction

Regular participation in physical activity among youth is positively associated with physical and psychological health and with some aspects of cognitive and academic performance (Bull et al., 2020). Physical activity could impact on academic performance through different direct and indirect learning, cognitive, emotional and physiological mechanisms (Rasberry et al., 2011; Barbosa et al., 2020). It was well demonstrated the close relationship between physical activity and academic achievement, behavior outcomes, psychosocial and cognitive functioning (Donnelly et al., 2016; Barbosa et al., 2020; Vasilopoulos and Ellefson, 2021). Moreover, many studies revealed the positive association between aerobic fitness, flexibility, and muscular strength (Gil-Espinosa et al., 2020) and the negative association between obesity (Martin et al., 2017) and sedentary time (Haapala et al., 2017) with academic achievement. Although research remains limited in investigating the relationship between healthy lifestyle habits (including physical activity, diet, screen time) and academic performance (García-Hermoso and Marina, 2017; Faught et al., 2017a) several studies showed consistent positive associations between fruit and vegetable consumption (Florence et al., 2008; Stea and Torstveit, 2014) and regular meal pattern (Stea and Torstveit, 2014) with better academic performance. In spite of these evidences, many children and adolescents have unhealthy eating habits, are engaged in more sedentary time than recommended, and do not meet the recommended daily 60 min of moderate-to-vigorous physical activity (Katzmarzyk et al., 2018; Bull et al., 2020; Paduano et al., 2021). In this context, school could have a crucial role to obtain changes on eating habits, physical activity level and sedentary behaviors in children. School-based food and nutrition education programs could promote the appropriate consumption of food in children since they usually consume one/two meals per day in school (Khambalia et al., 2012). School-based physical activity interventions could provide children the opportunity to participate in physical activity programs aimed at increasing physical activity level and promoting an active lifestyle (Gallotta et al., 2016, 2017). Moreover, school-based physical activity interventions could be useful to increase children's physical fitness and motor coordination (Gallotta et al., 2017), cognitive development (Gallotta et al., 2015; García-Hermoso et al., 2021) and academic performance (García-Hermoso et al., 2021; Loturco et al., 2022).

To date, cross-sectional (Faught et al., 2017a; Bleiweiss-Sande et al., 2019) and interventional studies (Wassenaar et al., 2020; García-Hermoso et al., 2021; Takehara et al., 2021) examined the relationship between some of these factors and academic achievement in children and adolescents. These studies also showed the need to better understand the relationships between multiple lifestyle factors and academic achievement.

Moreover, the long-term effects of physical exercise on children's academic performances have been studied by previous authors after manipulating quantitative aspects of physical exercise (Donnelly et al., 2016; Bugge et al., 2017; García-Hermoso et al., 2021). To our knowledge, no data are available regarding the effects of the manipulation of qualitative aspects of physical activity on children's academic achievement. The quality of physical activity in children primarily concerns the variety and the level of coordinative demands of the physical exercise contents (Gallotta et al., 2009). It is focused on the manipulation of the complexity of the physical exercise tasks thus requiring mental engagement (Tomporowski et al., 2015). Thus, physical education may provide children with a high-quality experience of physical activity, enhancing cognitive functions such as memory, reaction speed, attention, and concentration. This, in turn, can facilitate the learning process and lead to improved academic performance.

Previous studies demonstrated that long-term coordinative exercises had positive effects on children's cognition (Gallotta et al., 2015; Tomporowski et al., 2015) and that children's motor coordination was positively associated with their academic achievement (Ryu et al., 2021). Coordinative exercises include complex movements that place demands on children's executive processes (Best, 2010; Gallotta et al., 2015), providing a constructive basis for improved cognitive performances and therefore for the academic performances that are closely linked with them (Gunzenhauser and Nückles, 2021). The most available cross-sectional studies (Stea and Torstveit, 2014; Donnelly et al., 2016; García-Hermoso and Marina, 2017; Faught et al., 2017a; Barbosa et al., 2020) also showed the need to conduct longitudinal interventional designs to establish the causal direction of the association between multiple lifestyle factors and academic achievement.

Therefore, the first aim of this study was to examine the association between academic achievement (Italian language and mathematics skills) and anthropometric variables, fitness level (aerobic fitness, muscular strength, flexibility), gross motor coordination, physical activity level, sedentary time, attentional performance, fruit and vegetable consumption and meal frequency in primary school children.

The second aim of this study was to evaluate the effect of a qualitative physical education intervention on children's academic achievement by proposing two different exercise programs: a traditional physical education intervention and a coordinative physical education intervention conducted by a specialist physical education teacher. We hypothesized a possible selective improvement of children's academic performance in the coordinative group compared to the traditional group.

The third aim of this study was to examine whether variations of anthropometric variables, fitness level (aerobic fitness, muscular strength, flexibility), gross motor coordination, physical activity level, sedentary time, attentional performance, fruit and vegetable consumption, meal frequency and type of physical education intervention could predict children's academic achievement variations (Italian language and mathematics skills).

2 Materials and methods

2.1 Selection of schools and allocation to intervention

This intervention study was conducted in all classes (from Grade 3 to Grade 5) of three primary schools in a rural area close to Rome (Italy). The area was included in a circle of 5 km radius from a landmark to obtain a sample with comparable environmental characteristics. This comprised a total of 5 schools. We further excluded those schools that were already engaged in physical activity programmes / interventions. The remaining 3 schools were invited and agreed to participate in the study. The schools were the experimental units that received the intervention and, therefore, were either randomized to traditional physical education group or coordinative physical education group (Thomas et al., 2015).

2.2 Participants

Among the 266 eligible children, one hundred and sixty-one primary school children aged 8–11 years volunteered to participate in this study. The distribution of students in the classroom was as follows: there were 55 Grade 3 children aged 8 to 9 years, 62 Grade 4 children aged 9 to 10 years, and 44 Grade 5 children aged 10 to 11 years. After the randomization process, the traditional physical education group consisted of 78 participants (33 girls and 45 boys), while the coordinative physical education group comprised 83 participants (38 girls and 45 boys). Children were eligible if they had no attention-deficit disorders, academic and learning difficulties, dyslexia, developmental and neurological disorders, medical conditions that would affect study results or limit physical activity. All children met the inclusion criteria.

The University Ethical Committee approved this investigation (Rif 3,502 Prot. 1883/15) in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Informed written consent was obtained from both parents prior to study participation.

2.3 Variables assessment

2.3.1 Academic achievement

Before and after the intervention, children's academic achievement (Italian language and mathematics skills) was rated made by generalist school teachers on a 5-point rating scale ranging from 1 to 5 with ascending numbers indicating higher achievement (1: much below average, 2: below average, 3: average, 4: above average, 5: much above average) (Henricsson and Rydell, 2006; Thorell et al., 2013).

2.3.2 Anthropometric variables

Before and after the intervention, children's weight, height, body mass index (BMI), and body fat mass percentage (FM%) were evaluated. Weight and height measurements were taken using a scale and a stadiometer, respectively, with accuracy to the nearest 0.5 kg and 0.1 cm. BMI was calculated by dividing the weight in kilograms by the square of the height in meters. The FM% was determined through a multi-frequency hand-to-foot bioelectrical impedance method (IOI 353 analyzer, Jawon Medical Co. Ltd., Seoul, South Korea).

2.3.3 Physical fitness assessment

2.3.3.1 Aerobic fitness

Before and after the intervention, children's aerobic fitness level was evaluated using the PACER test. Children had to run as long as possible back and forth across a 15-meter space at a specified pace that got faster each minute (Welk et al., 2013). Then, a conversion chart was used to convert scores on the 15-M PACER to a 20-M score (Welk et al., 2013) to enter the Léger equation (Léger et al., 1988) for estimating VO_{2max} values (ml. kg^{-1}. min^{-1}).

2.3.3.2 Muscular strength and endurance

Before and after the intervention, children's muscular strength was assessed by the curl-up and push-up tests for abdominal muscles and upper body strength and endurance, respectively. Children had to perform as many curl-ups as possible until reaching a maximum of 75 repetitions and as many 90° push-ups as possible at a specified pace. The score was the number of correctly performed curl-ups and push-ups (Welk et al., 2013).

From the two tests, a single muscular strength z-score was calculated. Each individual test score was standardized using the formula: z-standardized value = (value − mean)/SD. The muscular strength z-score was obtained by averaging the two standardized scores (Martinez-Gomez et al., 2012).

2.3.3.3 Flexibility

Before and after the intervention, children's flexibility was assessed by the back-saver sit and reach test. Children had to reach as far as possible with one leg straight while sitting at a sit-and-reach box. The measurement was performed on one side (right, left) at a time. The score was recorded to the last whole centimeter, with distances above 30 cm being recorded as 30 (Welk et al., 2013).

2.3.4 Gross motor coordination

Before and after the intervention, children's gross motor coordination was assessed by the four subtests (balance beam test, jumping laterally test, hopping on one leg over an obstacle test, shifting platforms test) included in the Körperkoordinationstest Für Kinder battery (Kiphard and Schilling, 2017). The motor quotient (MQ), a comprehensive indicator of motor coordination adjusted for age and gender, was then computed using the raw values obtained from the four subtests included in the battery (Kiphard and Schilling, 2017).

2.3.5 Attentional performance

Before and after the intervention, children's attentional performance was evaluated using the d2-R test of attention. This test aimed to assess their ability to concentrate on a specific stimulus or task while disregarding distractions from competing stimuli. The d2-R test is a paper-and-pencil letter cancellation test to assess concentration and sustained attention under stress induced by time constraints. Children's processing speed and amount of work completed (TN), concentration performance (CP), performance accuracy (E%), and attentional and inhibitory control (TP) were assessed (Brickenkamp et al., 2013).

2.3.6 Physical activity level

Before and after the intervention, children's physical activity level was evaluated using the self-administered Italian version of the Physical Activity Questionnaire for Older Children (PAQ-C-It) (Gobbi et al., 2016). The questionnaire is a 7-day recall instrument comprising nine questions related to sports, games, physical activities at school, and leisure-time activities, including the weekend. Each question is rated on a scale from 1 to 5, and the final score is calculated by averaging the scores from all the questions (Crocker et al., 1997).

2.3.7 Sedentary time

Before and after the intervention, self-reported sedentary time was evaluated through a parental proxy interview. Children's parents were requested to provide information on the average number of minutes their children spent reading, watching television, playing video games, and using the computer on both weekdays and weekends, excluding school hours (Coombs et al., 2013).

2.3.8 Fruit and vegetable consumption

Before and after the intervention, children's fruit and vegetable consumption was assessed by a 7-day diet record. Children were asked about their weekly fruit and vegetable consumption frequency, with response options scored as follows: 1 = "never," 2 = "less than once a week," 3 = "once a week," 4 = "2 to 4 days a week," 5 = "5 to 6 days a week," 6 = "once a day, every day," and 7 = "every day, more than once" (Vereecken et al., 2008).

2.3.9 Meal frequency

Before and after the intervention, children's meal frequency was assessed by a 7-day recall questionnaire. Meal frequency was assessed by questions such as: "How many times do you have breakfast in a week?" The same was asked for lunch, dinner, mid-morning and afternoon meals. Response alternatives ranged from never to 7 days a week. The response options for all items were scored as 1 = "never/once a week," 2 = "2 to 3 times a week," 3 = "4 to 6 times a week," 4 = "every day" (Nardone et al., 2015).

Prior to the administration, children were given instructions to complete all the questionnaires, which were group-administered in classrooms under quiet conditions. They were provided with sufficient time to fill out the questionnaires, and an experimenter was present to address any questions raised by the children.

2.4 Physical education intervention

Both physical education interventions were conducted over a period of 5 months, comprising two 1-h sessions per week. The interventions were designed and led by the same specialist physical education teacher. The two interventions varied in the type and mode of physical activities in which children participated, but they were similar in terms of their overall structure, duration, and relative intensity. The OMNI scale (Utter et al., 2002) was used to monitor intensity and ensure that there were no differences between the two interventions. In both interventions, each lesson consisted of a 15-min warm-up, followed by 35 min of moderate-to-vigorous physical activities (MVPA) with an intensity level ranging from 5 to 8 RPE (U.S. Department of Health and Human Services, 2008). Finally, each session concluded with 10 min of cooldown and stretching exercises.

The *traditional* physical education intervention aimed primarily to enhance children's flexibility, strength, and cardiovascular endurance development (DPR, 2013). The specialist physical education teacher proposed flexibility and strength exercises and circuit training for cardiovascular health without complex coordinative demands with the main goal of developing children's fitness and health (Gallotta et al., 2015, 2016, 2017) (see Appendix for full protocol description).

The *coordinative* physical education intervention aimed primarily at fostering the development of children's coordination and dexterity. It consisted of four didactic modules (sport-games module, rhythmic activities module, gymnastics module, and fitness activities module) designed to offer children diverse opportunities to engage in and learn various sports and unconventional activities.

The *sport-games module* was characterized by the sport-unspecific use of different types of balls in the context of mini-games.

The *rhythmic activities* module was characterized by the execution of rhythmic sequences on a musical base with small tools.

The *gymnastics module* was characterized by the high variety of preparatory exercises for basic gymnastics fundamentals.

The *fitness activities module* was characterized by exercises with high coordinative demands to favor strength, endurance, speed, and flexibility development (Gallotta et al., 2015, 2016, 2017) (see Appendix for full protocol description).

2.5 Statistical analysis

2.5.1 General characteristics of the participants

Children's baseline characteristics by intervention group (traditional physical education group / coordinative physical education group) were described by means and standard deviations.

2.5.2 Association between academic achievement and all other measured variables

Pearson's correlation analysis was used to explore the relationships between academic achievement (Italian language and mathematics skills) and anthropometric (BMI, %FM), aerobic fitness (VO_{2max}), muscular strength (muscular strength z-score), flexibility, gross motor coordination (MQ), attentional (TN, CP, E%, TP), physical activity (physical activity level, sedentary time), fruit and vegetable consumption, and meal frequency variables before intervention. A multiple linear stepwise regression analysis was then performed to examine the associations of academic achievement with correlated variables at baseline.

2.5.3 Evaluation of the effects of different physical education interventions on academic achievement

All results were expressed as mean ± standard deviation. Within the intervention type, differences in the baseline academic achievement scores were verified by means of an unpaired comparison t-test. Thus, academic achievement scores were analyzed using a 2 × 2 mixed ANOVA with intervention type (traditional vs. coordinative) as between factor and time (pre vs. post) as within factor. Effect size was also calculated using Cohen's definition of small, medium, and large effect size (as partial $\eta^2 = 0.01, 0.06, 0.14$). Significant interactions were further analyzed by means of appropriate *post hoc* analysis.

For the academic achievement scores evaluated after the intervention, we calculated the absolute variation (Δ) and the percentage of variation (Δ%) with respect to its preintervention value (postintervention value — preintervention value). An unpaired comparison t-test was then performed to examine differences between the two types of intervention on Δ and on Δ% in academic achievement scores.

2.5.4 Relationship between academic achievement variations and several potential predictors

We calculated Δ for all other variables. A multinomial logistic regression analysis was then used to assess whether the absolute variation of BMI, FM%, aerobic fitness level (VO_{2max}), muscular strength (muscular strength z-score), flexibility, gross motor coordination (MQ), attentional performance (TN, CP, E%, TP), physical activity level, sedentary time, fruit and vegetable consumption, meal frequency and intervention type predicted academic achievement categories. The absolute variation of academic achievement was examined as three categories (improvement, invariance, and worsening). "Invariance category" was set as reference group. Intervention type was added as factor, the absolute variation of BMI, FM%, aerobic fitness level, muscular strength, flexibility, gross motor coordination, attentional performance, physical activity level, sedentary time, fruit and vegetable consumption and meal frequency were included in the analyses as covariates. All variables were tested in the same model, controlling the effect of each other.

Statistical significance was defined as $p \leq 0.05$. Statistical analysis was performed with SPSS Version 27.0 statistic software package.

3 Results

Children's baseline characteristics by intervention group are shown in Table 1.

3.1 Association between academic achievement and all other measured variables

Aerobic fitness, muscular strength, gross motor coordination, physical activity level and dinner meal frequency at baseline significantly correlated with Italian language skill, while aerobic fitness,

TABLE 1 Children's baseline characteristics of traditional physical education group and coordinative physical education group (mean ± standard deviation).

	Traditional PE group (*n* = 78)			Coordinative PE group (*n* = 83)		
Weight (kg)	38.8	±	11.5	37.3	±	8.9
Height (cm)	137.3	±	8.7	137.8	±	7.3
BMI (kg/m^2)	20.2	±	4.1	19.5	±	4.0
FM%	20.3	±	8.6	19.2	±	8.6
Physical activity level (score)	2.2	±	0.7	2.2	±	0.7
Sedentary time (min)	678.5	±	232.3	478.6	±	251.8
TN (score)	370.6	±	81.4	404.7	±	95.7
CP (score)	128.8	±	32.3	103.3	±	41.3
E%	7.4	±	4.4	16.9	±	8.4
TP (score)	343.5	±	78.3	335.5	±	82.9
Italian language skill (score)	3.2	±	1.1	3.0	±	1.1
Mathematics skill (score)	3.1	±	1.1	3.2	±	1.2
Flexibility (cm)	16.2	±	5.6	15.9	±	6.2
Muscular strength (*z*-score)	0.0	±	0.8	0.2	±	0.7
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	43.8	±	2.4	42.7	±	3.5
MQ (score)	76.2	±	12.1	77.1	±	11.6
Fruit consumption (score)	4.1	±	1.7	4.6	±	1.7
Vegetables consumption (score)	4.1	±	1.6	4.2	±	1.6
Breakfast meal frequency	3.7	±	0.7	3.6	±	0.8
Mid-morning meal frequency	2.6	±	0.5	2.6	±	0.5
Lunch meal frequency	2.9	±	0.3	2.8	±	0.5
Afternoon meal frequency	2.4	±	0.6	2.6	±	0.6
Dinner meal frequency	2.9	±	0.2	2.8	±	0.4

PE, physical education.

muscular strength, gross motor coordination and physical activity level at baseline significantly correlated with mathematics skill (Table 2).

The application of the multiple regression analysis indicated that physical activity level, aerobic fitness and muscular strength at baseline predicted Italian language skill, although the percentage of variance it could explain was moderate ($R^2 = 21\%$) (Table 3).

Moreover, the multiple regression analysis indicated that physical activity level, gross motor coordination and aerobic fitness at baseline predicted mathematics skill, although the percentage of variance it could explain was moderate ($R^2 = 17\%$) (Table 4).

3.2 Evaluation of the effects of different physical education interventions on academic achievement

Differences in the baseline academic achievement scores of traditional group and coordinative group were verified ($p < 0.05$), but no significant differences were revealed.

The main effect of time revealed that children's Italian language ($F_{1,158} = 32.73$, $p < 0.001$, $\eta^2 = 0.172$) (3.06 ± 1.11 score vs. 3.34 ± 1.21 score) and mathematics ($F_{1,159} = 16.05$, $p < 0.001$, $\eta^2 = 0.092$) (3.17 ± 1.11 score vs. 3.34 ± 1.12 score) skills significantly improved after intervention. Moreover, ANOVA revealed a significant time x intervention type interaction on Italian language ($F_{1,158} = 12.37$, $p < 0.001$, $\eta^2 = 0.073$) and mathematics ($F_{1,159} = 20.80$, $p < 0.001$, $\eta^2 = 0.116$) skills, indicating the likely presence of differential effects of intervention type on academic achievement following the intervention. Specifically, Italian language and mathematics skills significantly improved only after traditional intervention (Figure 1).

Improvements across the intervention were analyzed using Δ and Δ%. The t-test comparison revealed that traditional intervention led to a higher improvement of academic achievement than coordinative intervention (Figure 2).

3.3 Relationship between academic achievement variations and several potential predictors

In order to model the relationship between the variation of academic achievement (academic achievement categories) and the variation of several potential predictors (BMI, FM%, aerobic fitness level, muscular strength, flexibility, gross motor coordination, attentional performance, physical activity level, sedentary time, fruit and vegetable consumption, meal frequency and intervention type) a multinomial logistic regression was performed. The variation of sedentary time [χ^2 (2) = 10.05, $p = 0.007$], fruit consumption [χ^2 (2) = 6.40, $p = 0.04$], and intervention type [χ^2 (2) = 7.31, $p = 0.03$] contributed significantly to the variation of Italian language skill. The variation of afternoon meal frequency [χ^2 (2) = 9.36, $p = 0.009$] and intervention type [χ^2 (2) = 9.35, p = 0.009] contributed significantly to the variation of mathematics skill. Table 5 presents the results of the multinomial logistic regression.

Sedentary time and fruit consumption increases were positively associated with the improvement in Italian language skill. Moreover, coordinative physical education intervention was associated with a lower probability of improvement in Italian language skill. A lower variation (reduction) of afternoon meal frequency was positively associated with the improvement in mathematical skill. Moreover, coordinative physical education intervention was associated with a lower probability of improvement in mathematical skill.

4 Discussion

4.1 Association between academic achievement and all other measured variables

The first aim of the present study was to examine the association between a wide range of individual, physical, cognitive and nutritional variables and the academic achievement of primary school children.

Results revealed that aerobic fitness, muscular strength, gross motor coordination, physical activity level and dinner meal frequency were related to Italian language skill, while aerobic fitness, muscular strength, gross motor coordination and physical activity level

TABLE 2 Correlation coefficients between academic achievement and variables measured at baseline.

	Italian language skill	Mathematics skill
Aerobic fitness (VO_{2max})	0.319**	0.277**
Muscular strength (*z*-score)	0.249**	0.221**
Gross motor coordination (MQ)	0.298**	0.294**
Physical activity level (score)	0.338**	0.309**
Dinner meal frequency	0.162*	

**$p \leq 0.01$ *$p \leq 0.05$.

TABLE 3 Multiple linear stepwise regression with Italian language skill as the dependent measure.

	Predictor variables	SE	Adjusted R^2	R^2	Change in R^2	*p*	*t*	β	F
Model 1	Physical activity level (score)	0.118	0.109	0.114	0.114	0.000	4.501	0.338	20.260
Model 2	Physical activity level (score)	0.116				0.000	3.907	0.288	
	Aerobic fitness (VO_{2max})	0.027	0.172	0.182	0.068	0.000	3.597	0.265	12.941
Model 3	Physical activity level (score)	0.116				0.000	3.589	0.263	
	Aerobic fitness (VO_{2max})	0.027				0.001	3.384	0.247	
	Muscular strength (*z*-score)	0.103	0.196	0.211	0.029	0.018	2.392	0.174	5.720

Variables used: aerobic fitness (VO_{2max}). muscular strength (muscular strength z-score), gross motor coordination (MQ), physical activity level, dinner meal frequency at baseline.

TABLE 4 Multiple linear stepwise regression with mathematics skill as the dependent measure.

	Predictor variables	SE	Adjusted R^2	R^2	Change in R^2	*p*	*t*	β	F
Model 1	Physical activity level (score)	0.120	0.089	0.095	0.095	0.000	4.077	0.309	16.625
Model 2	Physical activity level (score)	0.120				0.001	3.392	0.256	
	Gross motor coordination (MQ)	0.006	0.136	0.147	0.052	0.002	3.085	0.233	9.520
Model 3	Physical activity level (score)	0.119				0.002	3.137	0.236	
	Gross motor coordination (MQ)	0.007				0.023	2.303	0.181	
	Aerobic fitness (VO_{2max})	0.029	0.156	0.172	0.025	0.033	2.151	0.168	4.628

Variables used: aerobic fitness (VO_{2max}), muscular strength (muscular strength z-score), gross motor coordination (MQ), physical activity level at baseline.

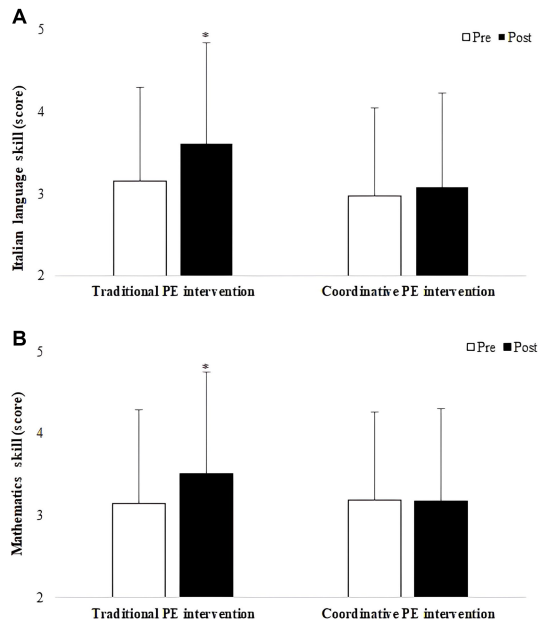

FIGURE 1
Pre- and post- intervention individual scores (mean ± SD) for Italian language **(A)** and mathematics **(B)** skills. Abbreviation: PE, physical education. *$p < 0.001$ post vs pre.

positively correlated with mathematics skill. Additionally, results of the multiple regression analysis revealed that the level of physical activity and aerobic fitness were significant predictors of both Italian language and mathematics skills. Previous studies suggested that physical activity may impact on academic performance through a variety of direct and indirect emotional, cognitive, physiological, and learning mechanisms, revealing that cognitive and motor abilities develop concurrently (Rasberry et al., 2011). Children who have more and more well-developed motor abilities could attain a greater range of motor experiences that create the foundation for better academic performances (Salaj and Masnjak, 2022). The pre-frontal cortex brain area is involved in both the processing of motor information and cognitive tasks. Therefore, children with greater motor abilities show better achievement, since the stronger motor skills strengthen the neural connections that also assist children in many academic tasks (Tomporowski and Pesce, 2019). Moreover, evidence supported the relationship of physical activity and aerobic fitness with brain structure and function, and therefore with cognition and learning (Donnelly et al., 2016; Erickson et al., 2019). Physical activity causes changes to neural architecture and to brain function, inducing consequently changes in cognitive performance (Meijer et al., 2020). There is evidence suggesting that physical activity provides selective advantages to neural structures that specifically support certain aspects of cognition. Furthermore, research indicates that higher aerobic fitness might exert a targeted impact on cognitive functions, which are underpinned by specific brain structures. Research findings provide evidence that physical activity and physical fitness positively influence children's mental functioning, indicating that children who are physically fit tend to outperform less-fit children on cognitive tasks. Physical activity-related changes in children's brain function and cognition (e.g., concentration, attention, memory, information processing) induce gains in academic performance, also providing opportunities for fundamental motor skill acquisition (Donnelly et al., 2016; Erickson et al., 2019). Furthermore, it has been observed that physically fit children exhibit quicker and more robust neuro-electrical brain responses during reading compared to their less-fit peers. This finding suggests that a higher level of fitness may be linked to a more extensive network of words and their meanings, along with an improved capacity to identify and/or correct syntactic errors (Scudder et al., 2014).

4.2 Evaluation of the effects of different physical education interventions on academic achievement

The second aim of the present study was to evaluate the effect of a traditional physical education intervention and of a coordinative physical education intervention on children's academic achievement. Our findings revealed a general improvement of academic skills after intervention, suggesting that physical activity may enhance children's academic performance and cognitive outcomes (Donnelly et al., 2016; Barbosa et al., 2020; Vasilopoulos and Ellefson, 2021) and confirming that children engaged in regular physical exercise may perform much better in mathematics and language skills than inactive students (Álvarez-Bueno et al., 2017). Moreover, the positive effects of physical education interventions on academic performance could be due to the facilitating effects of physical activity on children's mental function, intelligence and cognitive development (Singh et al., 2019).

Davis et al. (2011) proposed the existence of a direct path between exercise and cognitive performance due to a direct result of neural stimulation by movement. Currently, it is hypothesized that a positive effect of physical activity on cognitive functions is partly caused by

TABLE 5 Multinomial logistic regression predicting academic achievement categories.

	Improvement	Worsening
Italian language skill	OR (95% CI)	OR (95% CI)
Δ sedentary time	1.00 (1.00–1.01)**	1.00 (1.00–1.00)
Δ fruit consumption	1.26 (1.03–1.53)*	0.93 (0.66–1.32)
Intervention type[a]		
Coordinative intervention	0.26 (0.09–0.75)*	1.22 (0.19–7.71)
Mathematics skill		
Δ afternoon meal frequency	3.30 (1.38–7.91)**	0.56 (0.14–2.30)
Intervention type[a]		
Coordinative intervention	0.26 (0.08–0.88)*	10.59 (0.52–215.19)

Invariance was chosen as reference group for the outcome. All variables were tested in the same model, controlling the effect of each other.
*$p < 0.05$, **$p < 0.01$. OR odds ratio, CI confidence interval, CP concentration capacity.
[a]*Reference category is "traditional intervention".*

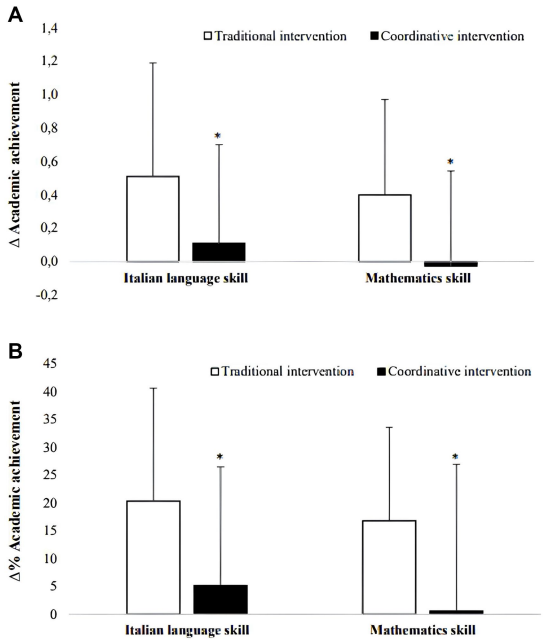

FIGURE 2
Variation (Δ) **(A)** and parcentage of variation (Δ%) **(B)** of academic achievement (± SD). *$p < 0.001$ traditional intervention vs coordinative intervention.

physiological changes in the body such as increased levels of brain-derived neurotrophic factor (BDNF), that facilitates learning and maintains cognitive functions by improving synaptic plasticity and acting as a neuroprotective agent, increased brain circulation and improved neuroelectric functionality (Latomme et al., 2022). Therefore, neuroscientific evidence of the beneficial effects of exercise and physical activity on cognition supports a three-level model to explain the interaction between brain and movement: (i) increased vascularization augmenting brain activity; (ii) the release of neurotransmitters and BDNF which favor neurogenesis, memory, attention and motivation; (iii) the development of complex movement-related neural circuits and their interconnection with the executive brain functions (Doherty and Forés Miravalles, 2019). Moreover, different psychosocial mechanisms that accompany physical activity could induce the improvement of cognitive and academic performances after chronic exercise (Davis and Lambourne, 2009; Vella et al., 2023). In particular, participation in well-structured organized physical activity could positively impact on psychological variables such as mastery and self-efficacy, contributing to beneficial cognitive changes (Davis and Lambourne, 2009; Vella et al., 2023).

Engaging in structured and complex physical activities and games that involve motor learning, interaction with the environment, and group cooperation demand mental processes inherent to exercises that can enhance cognitive functions, including attention and concentration capacity. Thus, children engaged in physical activities that promote cooperation, sharing, and learning to follow rules learn skills that transfer to classroom setting (Tomporowski et al., 2008). Moreover, physical activity during the school day may induce arousal and reduce boredom, which can lead to increased attention span and concentration (Tomporowski et al., 2008).

However, our findings revealed that the type of intervention had differential effects on academic variables. In particular, results showed that the traditional physical education intervention led to greater improvement on both Italian language and mathematical skills, compared to the coordinative physical education intervention. The improvement of Italian language skills could be associated with structural and functional cortical development (Martin-Martinez et al., 2023) induced by the traditional physical education intervention which also included complex aerobic activities (e.g., running games) that increased activity in the prefrontal cortex and improved performance on tasks requiring executive functioning as well as having a positive effect on mathematics achievement (Davis et al., 2007). Moreover, the use of various number and counting movement games and activities during the traditional physical education intervention could justify the greater improvement on mathematical skills after this intervention.

Our results were not in line with previous studies suggesting that physical exercise involving greater coordinative and attentional demands had a great beneficial effect on cognitive performance (Tomporowski and Pesce, 2019; Kolovelonis et al., 2022), due to the well-documented close relationship between motor coordination and cognitive performance (Schmidt et al., 2017) and the activation of specific neuronal structures, such as the frontal cortex and the cerebellum, which are common to both cognition and motor coordination (de Bruijn et al., 2021).

We supposed that the lower improvement of children's academic performance after the coordinative physical education intervention could be due to the excessive stress induced by the mixed physical and cognitive load proper of coordinative exercises (Gallotta et al., 2012, 2015) and therefore, to the less fatiguing cognitive involvement of traditional intervention compared to a mixed physical and cognitive load of coordinative intervention (de Bruijn et al., 2021). However, activities with high coordination demands seemed to be a valid training for executive functions by movement, since the cognitive load required to execute complex movements is crucial for inducing neuroplastic changes that underlie skillful movement performances (Gallotta et al., 2015).

These scientific evidences should be considered when designing physical education school programs in the choice of the contents: indeed, to avoid a potential fatiguing effect on children, especially when the following classrooms are challenging, a balance between coordinative demands and traditional physical exertion could be recommendable.

4.3 Relationship between academic achievement variations and several potential predictors

The third aim of this study was to identify potential predictors of children's academic achievement variations. Results showed that Italian language skill improvement was positively associated with sedentary time and fruit consumption increases. It could be hypothesized that the Italian language study requires more sitting time to be proficiently carried out as they involve writing and thinking tasks. Indeed, as reported in a recent systematic review, school-based physical education programs seem to be more effective on math academic performance than on language and reading abilities (Loturco et al., 2022).

Moreover, although the precise association between fruit and vegetable consumption and academic performance remains uncertain, there are several possible explanations. The nutrients present in fruits and vegetables may play a role in protecting the body against infections and decreasing the likelihood of nutrient deficiencies. Consequently, this could lead to a possible reduction in school absenteeism and allow for more time spent learning (Slavin and Lloyd, 2012; Wolfenden et al., 2021). In addition, vegetables and fruits provide fiber, which helps prevent constipation and consequently may alleviate discomfort and irritability in children, avoiding distractions from learning (Rajindrajith et al., 2013; Wang et al., 2013). Moreover, Bleiweiss-Sande et al. (2019) reported that the consumption of less healthful food in school children was associated with poorer academic achievement, supporting the negative relationship between junk foods and academic achievement. Furthermore, considering that children have smaller stomachs, they often require snacks in addition to meals to ensure sufficient nutrient intake and energy to support their growth and development (Raymond and Morrow, 2022). Therefore, it is possible that incorporating snacks of fruits and vegetables throughout the day might help alleviate hunger and offer a healthy source of energy, potentially enhancing children's focus on schoolwork or homework.

To the best of our knowledge, no other studies examined the association between such a wide range of health behaviors, physical fitness components, coordinative and cognitive variables and academic achievement among school children. Previous research has addressed mainly to adolescents reporting that frequent consumption of vegetables and fruits, breakfast and dinner with family and regular physical activity were positively associated with higher levels of academic achievement in a 11–15-year-old sample (Faught et al., 2017b). Other results showed that College students adhering to public health recommendations for lifestyle behaviours have modestly higher grades (Wald et al., 2014).

Unexpectedly, our coordinative physical education intervention was associated with a lower probability of improvement in Italian language and mathematical skills. Schmidt et al. (2017) highlighted the positive association between children's motor coordination and their academic achievement, mediating by executive functions. More recently, de Bruijn et al. (2021) examined the effects of two different 14-week physical education interventions (aerobic versus cognitively-engaging physical activity) on primary school children's cognition and academic achievement (de Bruijn et al., 2021). They did not find significant differences after interventions between the groups probably due to no significant differences in brain activation changes between the groups, indicating that the type of intervention did not result in changed brain activation patterns and therefore in measurable changes in cognition and academic achievement. These contradictory results could be due to the difficulty to realize physical activity interventions that are purely aerobic or purely coordinative and cognitively-engaging. Moreover, it is also to consider that academic performance is a complex dominion that depends on many interrelated factors such as genetic, socio-economic status, school environment, individual differences and it is also the result of multiple brain functions, such as memory, attention, concentration, making it difficult to interpret conclusions of studies examining the effect of different types of physical activities on children's executive functions and academic achievement.

The present study is currently being implemented to higher educational stages to investigate if different types of physical activity and sports in combination with healthy lifestyle habits could affect academic achievement in middle-school, high-school, and university students. Specifically, different physical activity and sport interventions could lead to facilitation in the learning process also in adolescents and youngsters in relation to the same abilities reported in the present study or to other academic skills (Gallotta et al., 2020).

5 Limitations

Limitations of the study include the lack of assessment of further cognitive functions such as inhibition, shifting, updating and working memory in addition to the attentional performance.

Another limitation is that academic achievement was measured with a scale ranging from 1 to 5 (Henricsson and Rydell, 2006; Thorell et al., 2013). However, this scale was chosen in order to similarly reproduce the Italian primary school grades system which currently ranges from 1 to 4 (corresponding to in the process of first acquisition, base, intermediate, advanced level, respectively and referring to four different learning levels).

It is to note that PAQ-C questionnaire relies on subjective responses from the individual and may not be as accurate or comprehensive as more sophisticated monitoring tools, such as wearable devices that continuously track physical activity.

Finally, the study involved children living in a rural area. Gallotta et al. (2011) verified that living in rural or urban setting can influence training adaptations. Further studies should verify the effect of different physical education interventions on fitness and coordinative abilities in different living settings.

6 Conclusion

Motor ability and lifestyle habits may have a positive influence on academic achievement in children. Specifically, aerobic fitness and physical activity level are linked to better academic performance. In the present study, traditional physical education intervention resulted to be more effective on both Italian language and mathematical skills.

Some academic skills are more related to the time spent studying, especially in primary school children who are acquiring some notions for the first time. Therefore, physical education interventions in primary school are necessary to balance and limit the sedentary time.

The complex multicomponent relation between academic achievement and such a wide range of individual variables leads to a large number of interesting discussions and encourages needs to realize further study with rigorous and longitudinal research protocols.

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 University Ethical Committee of Sapienza University of Rome (Rif 3502 Prot. 1883/15). 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

MCG: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft. VB: Investigation, Methodology, Writing – review & editing. GZ: Data curation, Formal analysis, Software, Writing – review & editing. DC: Data curation, Formal analysis, Writing – review & editing. LF: Data curation, Investigation, Writing – original draft. SM: Conceptualization, Methodology, Writing – review & editing. LG: Conceptualization, Formal analysis, Methodology, Writing – review & editing. CB: Conceptualization, Methodology, Supervision, 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.2024.1412266/full#supplementary-material

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How the perfectionistic climate of a sports team predicts the athletic performance of elite athletes: a case study of the CUBAL women's basketball team

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Objective: In competitive sports, understanding how the perfectionistic climate within teams influences the performance of elite female athletes can provide valuable insights for enhancing coaching practice and athletic achievement. Based on the cognitive appraisal theory of stress, this study constructs a dual-path model using stressors and coping strategies as mediators, referred to as the Perfectionistic Climate on Athletic Performance model (PCPM). The study explores the predictive role of the perfectionistic climate within sports teams on the athletic performance of elite female basketball players.

Methods: The empirical study the relationships among the variables in the model using a sample of 125 core players from the top-level women's basketball teams in the 24th CUBAL24 tournament in 2022. A Structural Equation Modeling (SEM) analysis was conducted using AMOS 20.0, primarily employing the bias-corrected Bootstrap method to test the dual-path model.

Results: The findings reveal double-edged paths towards a perfectionistic climate on athletic performance. In the positive pathway, a perfectionistic climate can positively predict athletic performance through challenge-related sources of stress and positive coping strategies. In the negative pathway, a perfectionistic climate can negatively predict athletic performance through threat-related sources of stress and negative coping strategies.

Conclusion: Coaches need to pay attention to athletes' cognitive evaluations of the perfectionistic climate as a source of pressure. By setting challenging goals, coaches can guide athletes to view the perfectionistic climate of the sports team as a source of challenging pressure, thus unleashing their potential. Coaches should actively guide athletes in coping with the pressure brought about by the perfectionistic climate, enhancing their ability to handle stress. This will enable athletes to better adapt to the team's perfectionistic climate and further improve individual and team athletic performance.

KEYWORDS

perfectionistic climate, challenge stressors, threat stressors, coping strategies, athletic performance

1 Introduction

Achievement Goal Theory posits that the action goals individuals set in specific achievement situations are the result of the interaction between personality traits and social environmental factors (Nicholls, 1984, 1989). Dweck and Leggett (1988) further explain that personality traits are variables that determine the prior probability of individuals setting action goals and engaging in corresponding behavioral patterns, while social environmental factors can subtly change individuals' action goals and behavioral patterns. Flett et al. (2002), building upon this idea, proposed a Preliminary Model of the Development of Perfectionism, which elaborates on the factors contributing to the formation of individual perfectionism and emphasizes the significant role of life experiences and the social environment in its development. Perfectionism is a tendency to not accept anything less than perfection (Stoll et al., 2008). It is a multidimensional personality trait (Frost et al., 1990) characterized by striving for flawlessness, setting excessively high standards for oneself, and being overly critical of one's behaviors or overly sensitive to mistakes (Rice and Preusser, 2002). Perfectionism is commonly found among athletes and has a significant impact on their athletic performance (Stoeber, 2011, 2012). Hill and Grugan (2020) introduced the concept of perfectionistic climate, building upon the Achievement Goal Theory and the Preliminary Model of the Development of Perfectionism. Perfectionistic climate refers to the informational cues and goal structure that align with the pursuit of perfect performance and the rejection of any flaws in achievement contexts. It extends the investigation of perfectionism from individual internal personality traits to external social environments. This study draws on previous research (Chen and Gogus, 2008; Hill and Grugan, 2020) and further suggests that a perfectionistic climate reflects the homogenized beliefs and expectations related to perfectionism that team members develop during social interactions.

It is well-known that an athlete's performance is directly affected by external factors such as climate conditions (Cheng and Zheng, 2019) and competition rules (Li, 2015), in addition to being influenced by innate attributes like genetic factors (Falahati and Arazi, 2019) and muscle fiber composition (Edman et al., 2019), as well as psychological elements such as achievement motivation (Zuber and Conzelmann, 2014) and emotional intelligence (Zhao et al., 2016), which includes team members' personalities (Beauchamp et al., 2007), and the psychological climate of the sports team. Previous research has shown that the motivational climate of a sports team (Duda, 1992; Philyaw, 2021), collective efficacy (Dithurbide et al., 2009; Muñoz et al., 2023) and team cohesion (López-Gajardo et al., 2023; Oh and Yoo, 2023) can significantly predict athletic performance. In the pursuit of victory, elite sports teams often develop a culture of striving for excellence, which can lead to the formation of a perfectionistic climate within the team. On one hand, this climate may represent a synonym for harsh demands and suppression of individuality; on the other hand, it can reflect an attitude of striving for excellence, serving as a cohesive force that drives the team and motivates continuous self-improvement. This climate can significantly predict athletes' performance. Elite sports teams often form a culture of pursuing excellence on the path to victory, and the sports team is likely to form an atmosphere of perfectionism. On the one hand, it may be a synonym for demanding perfection and suppressing individuality; on the other hand, it may also be an attitude of the team pursuing excellence, and it is a spiritual force that cohere the team and drives continuous self-transcendence. Previous research has focused on the relationship between individual-level internalized perfectionism and athletic performance (Hill et al., 2014), with some studies affirming that Olympic champions possess perfectionistic traits (Gould et al., 2002) while others view perfectionism as maladaptive and detrimental to performance (Anshel and Mansouri, 2005; Flett and Hewitt, 2005). However, the impact of a perfectionistic climate as an external factor on athletic performance remains unknown.

In the competitive arena, basketball stands out as a sport heavily depends on teamwork and individual skills, captivating not only because of the thrilling moments in the game but also due to the intricate psychology and team culture behind them. When discussing the athletic performance of elite basketball players, they are often admired for their extraordinary skills and remarkable physical abilities. However, rarely delve into a crucial factor: the perfectionistic climate within the team. Team sports are inherently complex social phenomena, and perfectionistic climate, as a crucial aspect of team culture, emphasizes the pursuit of perfection and the fear of failure. This climate permeates every decision and action of the athletes, affecting their mindset, motivation, and performance. A perfectionistic climate leads basketball players to have higher expectations of their performance but also intensifies their fear of failure. This complexity in mindset allows athletes to either excel exceptionally or make repeated mistakes due to excessive pressure during games. In summary, the perfectionistic climate offers a new perspective for predicting athletes' performance. In competitive sports, where winning is the goal, striving for excellence and ideal performance is a common objective for both coaches and athletes. Understanding how a perfectionistic climate affects athletic performance and under what circumstances it applies can offer valuable insights for coaching practices.

2 Theoretical basis and research hypothesis

Previous studies have reported that most athletes are exposed to a demanding environment where coaches expect them to achieve perfect athletic performances in training or competition (Krane et al., 1997; Udry et al., 1997; Lavallee and Robinson, 2007). Athletes often set standards for themselves that they perceive as excessively high or even unrealistic. Examining the perfectionistic climate within the athlete population can provide a better understanding of the overall social and psychological atmosphere and identify heterogeneous situations in athletic performance within a group perfectionistic environment. In training or competition settings, pressure related to perfectionism is pervasive. According to traditional views, pressure sources can induce stress in athletes, leading to a range of emotional, attitudinal, and behavioral responses. Lazarus and Folkman's (1984) Cognitive Appraisal Theory of Stress further suggests that individuals have different cognitive appraisals and subsequent responses when facing the same pressure source.

The Cognitive Appraisal Theory of Stress, also known as the Transactional Model of Stress, is a stress theory used to explain the cognitive appraisal and coping processes individuals undergo when faced with stressors (Jiang and Wang, 2022). Selye (1976) categorized stress into eustress (positive stress) and distress (negative stress),

where distress leads to negative emotions and adverse effects, while eustress generates feelings of happiness or motivation. Building upon this perspective, Cavanaugh et al. (2000) classified stressors into two categories: Challenge Stressors and Threat Stressors (also known as Hindrance Stressors), a categorization supported by several other scholars (Lepine et al., 2005; Podsakoff et al., 2007). Different individuals may perceive the same stressor as an obstacle or a challenge, thereby influencing their coping strategies for managing stressors (Pindek et al., 2019). Many studies have suggested that individuals facing stressors will inevitably have negative reactions. In reality, stressors can elicit both negative and positive reactions from individuals (Lazarus and Folkman, 1984). Previous research has shown that stressors can lead to negative attitudes and behaviors in individuals (Mawritz et al., 2014). However, the Stress Cognitive Appraisal Theory emphasizes that if individuals believe they have sufficient resources to cope with the stressors, they may adopt positive responses to overcome the adverse implications of stressors. Similarly, as a stressor, the perfectionistic climate can evoke either positive or negative responses in athletes depending on their perceived resources to cope with the stress. If athletes believe they have enough resources to cope with the perfectionistic climate, they may adopt positive coping strategies. Conversely, if they perceive the perfectionistic climate as harmful to their well-being and lack adequate resources to cope with it, they may adopt negative coping strategies, thereby affecting their athletic performance.

Based on the above, the present study adopts the Stress Appraisal Theory as the theoretical foundation, and constructs a dual-path theoretical hypothesis model to predict athletes' performance based on the perfectionistic climate, referred to as the Perfectionistic Climate on athletic Performance model (PCPM). This model aims to explore the potential mechanisms through which the perfectionistic climate influences athletes' performance, with the goal of reminding coaches to pay attention to athletes' adaptability to the perfectionistic climate, in order to further enhance individual and team athletic performance.

2.1 Chain mediation of challenging stressors on positive coping strategies

Challenge stressors refer to situations in which individuals believe they can overcome the stress and are motivated by the stress to achieve work goals (Jiang and Wang, 2022). Examples of challenge stressors include workload, job demands, and time pressure (Cavanaugh et al., 2000; Lepine et al., 2005; Crawford et al., 2010; LePine et al., 2015). These stressors are evaluated by individuals as pressures that need to be overcome in order to promote personal growth or achieve established goals. The appraisal of challenge stressors enhances individuals' expectations of achieving high levels of accomplishment, leading to favorable emotional, attitudinal, and behavioral outcomes and facilitating the attainment of implicit goals (Skinner and Brewer, 2002). Lepine et al. (2005) found that athletes who perceive a perfectionistic climate as a challenge stressor may have a higher pursuit of athletic performance. They are more willing to believe that putting in sufficient effort to overcome the pressures associated with growth or achieving established goals will result in satisfying and valuable outcomes. McCauley et al. (1994) demonstrated that individuals are more likely to experience growth in organizations with high levels of challenging job demands. Although challenge stressors can induce feelings of tension and have negative effects on job satisfaction, organizational commitment, or job performance, the evaluation of challenge stressors often generates positive emotions and attitudes (Lazarus and Folkman, 1984; Cavanaugh et al., 2000; Boswell et al., 2004). Individuals may experience happiness or even excitement (Selye, 1956) in response to challenging evaluations, and these positive emotional responses can counterbalance the negative effects of stress (Podsakoff et al., 2007). Challenging job demands are closely associated with higher levels of job satisfaction and engagement (Campion and McClelland, 1991). The Stress Cognitive Appraisal Theory suggests that stressors perceived as challenging can have a positive impact while inducing stress in employees. As long as employees can effectively cope with these challenges, they may achieve higher job performance, richer work experiences, or more advanced work skills (Sacramento et al., 2013), and the same applies to athletes. According to previous research (Lepine et al., 2005; Zhang et al., 2014), stressors perceived as challenging can generate expectations of greater future benefits for athletes, which can motivate them and counteract the negative implications of stress, resulting in higher levels of athletic performance.

Coping refers to the cognitive and behavioral efforts individuals make to manage internal and external demands that exceed their personal resources (Lazarus and Folkman, 1984). "Positive Coping Strategies" typically refer to adaptive and effective ways of dealing with stressors, such as problem-solving, seeking social support, and positive reframing. Stressors can elicit coping responses from individuals (Xie et al., 2019), and both stressor appraisal and coping strategies are integral to this process. According to the cognitive appraisal theory of stress, when external stressors are appraised as challenging, individuals attempt to reduce the impact of the stressors through positive coping strategies. Research by Hulbert-Williams et al. (2013) showed that if the situational demands are high but individuals believe they are within their capabilities and have sufficient resources to cope, they tend to appraise the situation as challenging, leading to positive coping. Similarly, if a perfectionistic climate is appraised as a challenging stressor by athletes, that is, as a pressure that can bring personal benefits or facilitate growth, they may employ positive coping strategies when they have adequate coping resources, aiming to mitigate or eliminate the impact of the stressor and enhance athletic performance.

By engaging in positive behaviors, individuals can reduce the impact of stressors. This can be achieved through external efforts to change or decrease the demands of stressors or through internal efforts to enhance one's ability to cope with them (Kahn et al., 1964). In the context of sports teams, athletes can adopt positive strategies to modify stressors and reduce their threat. Kahn et al. (1964) referred to this as an environment-directed coping strategy, which involves altering environmental demands, obstacles, resources, or degrees. However, since athletes operate at the lowest level of the organization and must comply with coaches and team arrangements, they often have limited capacity to change the team's environment, making it challenging to implement environment-directed coping strategies.

On the other hand, athletes can also enhance their own abilities to cope with stressors more effectively. Kahn et al. (1964) called this a self-directed coping strategy. For instance, in a workplace setting, performance pressure and high-performance demands may prompt employees to increase their efforts to achieve performance goals and prove themselves (Mitchell et al., 2018). Similarly, athletes can continuously learn new knowledge and sports skills to foster personal growth, which may instill confidence in facing challenges and coping

positively with stressors. Based on the above analysis, the following research hypothesis is proposed:

> H1: Perfectionistic climate is positively correlated with challenging stressors, challenging stressors are positively correlated with positive coping strategies, positive coping strategies are positively correlated with athletic performance, and challenging stressors mediate the relationship between perfectionistic climate and athletic performance. In other words, when athletes perceive a perfectionistic climate as challenging stressors, they are more likely to adopt positive coping strategies to enhance athletic performance.

2.2 Chain mediation of threat stressors and negative coping strategies

Threat stressors refer to the stressors that individuals perceive as difficult to overcome and as obstacles to achieving their goals (Jiang and Wang, 2022). These stressors are evaluated by individuals as unnecessary pressures that hinder personal growth or the accomplishment of established objectives. Examples of threat stressors include organizational politics, bureaucratic habits, red tape, role conflicts, lack of job security, and career stagnation. These negative stress events are characterized by their uncontrollable and ambiguous nature (Zhang et al., 2018), which can lead individuals to cope in a negative manner. "Negative Coping Strategies" typically refer to maladaptive or ineffective ways of coping, such as avoidance, denial, or substance use. Threat stressors can result in physical and emotional exhaustion, cognitive resource depletion, and decreased motivation among employees (LePine et al., 2004; Probst et al., 2007; Aryee et al., 2009). As a consequence, individuals may adopt passive coping strategies and exhibit a reduced ability to handle situational demands. Rodell and Judge (2009) research also confirmed that threat stressors can lead to feelings of inferiority and withdrawal. When faced with threat stressors, individuals often find it difficult to eliminate the potential external threat through their own efforts, which significantly undermines their self-efficacy (Zhang et al., 2018). They no longer believe that their efforts and learning can improve outcomes (LePine et al., 2004), resulting in negative reactions toward threat stressors. When threat stressors are strong, individuals may have limited autonomy in determining their work content and methods, leading to a low sense of control over their resources and efforts (Cavanaugh et al., 2000). Even if they make efforts to cope with threat stressors, they may struggle to obtain beneficial returns. Threat stressors can significantly deplete an individual's physiological and emotional energy, making it difficult to sustain the physical demands of work and maintain a positive work state (LePine et al., 2015). This depletion of physical and emotional resources may decrease the perceived availability of resources for athletes, further negatively influencing their athletic performance.

Previous research has analyzed the relationships between challenge stressors and threat stressors with motivation, organizational commitment, turnover intentions, turnover, withdrawal behaviors, and job performance. The results indicate a significant positive correlation between challenge stressors and the aforementioned variables, while a significant negative correlation exists between threat stressors and these variables (Crawford et al., 2010; Bennett et al., 2018; Webster and Adams, 2020). It can be inferred that when athletes perceive a perfectionistic climate as a threat stressor, it may have a negative impact on their performance. Li et al. (2005) pointed out that coping strategies are important mediating variables that connect the outcomes of training and competition with the psychological and physiological responses to stress, exerting a continuous impact on the direction and intensity of psychological changes. Levy et al.'s (2011) study found that coping strategies significantly affect athletic performance and partially mediate the relationship between pre-competition confidence and subjective performance.

Negative coping strategies involves adjusting one's interpretation of stressors without changing the objective situation, using strategies such as avoidance, distancing, or finding positive value in negative events (Lazarus and Folkman, 1984). For athletes, the stressor of perfectionistic climate is uncontrollable. On one hand, adopting negative coping strategies can provide psychological comfort and compensation (Mawritz et al., 2014). Psychologically distancing oneself from the stressor can reduce its adverse effects (Folkman et al., 1986). For athletes, since it may be challenging to change the perfectionistic climate stressor, they may exhibit tendencies such as psychological withdrawal, training fatigue, and avoidance of training. These behaviors allow athletes to temporarily escape the interference of the perfectionistic climate stressor and find some relief from the pressure brought about by the organizational atmosphere. As these behaviors are relatively covert in the organization, lacking aggressiveness and destructiveness, and do not have severe consequences, they are common coping strategies among athletes.

On the other hand, athletes may engage in destructive behaviors that violate organizational norms and harm the interests of the organization, such as self-sabotage, resistance to training, or threat the achievement of team goals. However, destructive behaviors are likely to be subject to organizational punishments, and thus, they are not commonly observed among athletes as negative coping strategies. Based on the above analysis, the following research hypothesis is proposed:

> H2: There is a significant positive correlation between perfectionistic climate and threat stressors, as well as between challenge stressors and negative coping strategies. There is a significant negative correlation between negative coping strategies and athletic performance. Furthermore, threat stressors and negative coping strategies mediate the relationship between perfectionistic climate and athletic performance. In other words, when athletes perceive a perfectionistic climate as a threat stressor, they are more likely to adopt negative coping strategies, further suppressing their athletic performance.

This study is based on literature to construct a research hypothesis path diagram (Figure 1) on the influence of perfectionist climate on the athletic performance of athletes to explore the dual-path influence mechanism of perfectionist climate on the athletic performance of athletes.

3 Research design

3.1 Participants

The overlap rate of the roster of women's basketball high-level sports teams in the top 24 of the Chinese University Basketball

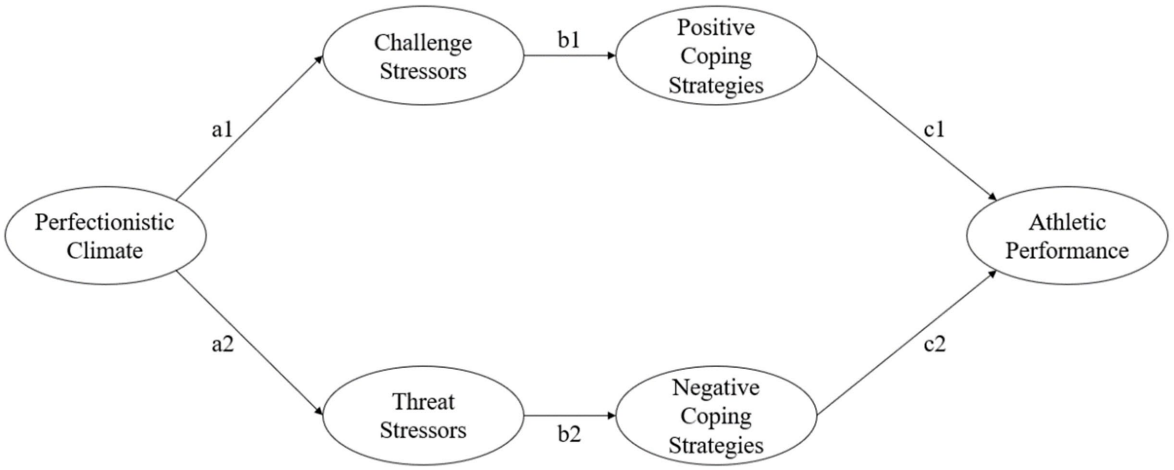

FIGURE 1
Perfectionistic climate on athletic performance model, PCPM (research hypothesis path: H1 = a1 × b1 × c1; H2 = a2 × b2 × c2).

Association (CUBAL) over the past 5 years is 87.60%. The top 24 teams in the league exhibit a "pyramid" effect, and the performance of athletes from these teams is sufficiently stable. Previous literature (Su et al., 2022) has indicated the presence of free-riding issues in team cooperation projects. Therefore, it is more reasonable to select core players (operationally defined as the top six players in terms of average points per game within the team) for the study. Based on the aforementioned analysis, this study will focus on the core players from the women's high-level basketball teams in the top 24 of the 24th CUBAL tournament held in 2022. The Academic Ethics Committee of the School of Physical Education and Sport, Beijing Normal University, approved the research protocol of this study. The inclusion criteria include: (1) being a member of the top 24 high-level women's basketball teams in the 24th CUBA; (2) being a core player on the team; (3) ranking among the top six in individual average points scored within the team. The exclusion criteria include: (1) players with an average score of zero; (2) players with an average playing time of less than 5 min; (3) players who self-reported injuries during the competition period.

Initially, we consulted the China Student Sports website[1] to retrieve the list of the top 24 high-level women's basketball teams and the list of core players for the 24th CUBAL,[2] and from this information, we established an overall sampling frame. We employed a snowball sampling method triggered by point-to-point cues and contacted target athletes individually through online platforms such as TikTok,[3] Wotobuy,[4] and Weibo.[5] This approach ensured that our study achieved a 100% completion and valid response rate for the questionnaire. The relevant details have been reported in the main text. For this study, we used the semPower package in the R programming language to conduct an *a priori* analysis and determine the minimum sample size required (Moshagen and Bader, 2023). According to the calculated degree of freedom was 398, with the minimum sample size required being over 77. Our study had an effective sample size of 125, which met the minimum sample size requirement. This eliminated the risk of low statistical power due to insufficient sample size. The statistical power of our study was 0.97, which is considered good (Cohen, 1988) as it is above the 0.80 threshold. These results indicate that our study had strong statistical power.

3.2 Instrument

3.2.1 Perfectionistic climate

The Perfectionistic Climate Questionnaire-Sport (PCQ-S) was adapted from the study conducted by Grugan et al. (2021). The questionnaire was measured using a 7-point Likert scale and comprised five constructs: Expectations, Criticism, Control, Conditional Regard, and Anxiousness. Each construct consisted of five items. The items went through a process of translation, refinement, and back-translation, resulting in a Chinese version of the questionnaire with a total of 20 items, such as "The coach expects us to perform perfectly on the field or in training" and "Even for small mistakes, the coach criticizes us." The original scale's McDonald's Omega (ω) ranges from 0.82 to 0.86, with expectations = 0.82 (95% CI range = 0.77 to 0.85); criticism = 0.85 (95% CI range = 0.81 to 0.88); control = 0.84 (95% CI range = 0.80 to 0.88); conditional regard = 0.86 (95% CI range = 0.82 to 0.89); anxiousness = 0.84 (95% CI range = 0.80 to 0.87). The factor loadings of the first-order model range from 0.67 to 0.92, indicating that the original scale reportedly possesses good reliability and validity.

3.2.2 Stressors

The measurement method for stressors in this study was based on the research reports of Cavanaugh et al. (2000) and LePine et al. (2004), and adapted from the Task Specific Stressor Scale (TSS) developed by LePine et al. (2015), modified to fit the sports context. Each item underwent translation, refinement, and back-translation processes, resulting in a Chinese version of the scale comprising a total of 16 items, such as "I take training or competition tasks seriously and

1 www.sports.edu.cn
2 www.sports.edu.cn/web/notice/images/20222231645585483854_99.pdf
3 https://www.douyin.com/
4 https://www.xiaohongshu.com/
5 https://weibo.com/

make efforts to complete them" and "I feel that the resources needed to complete training or competition tasks are insufficient." The scale was measured using a 7-point Likert scale. Among the items, 10 items measured challenge stressors (CS), including time pressure, task complexity, responsibility, and obligations as job demands, while 6 items measured threat stressors (TS), including task ambiguity, lack of resources, and interpersonal conflicts as job demands. The Confirmatory Factor Analysis (CFA) of the original scale yielded the following results: $\chi^2 = 698.29$, df = 293, CFI = 0.91, RMSEA = 0.09, SRMR = 0.09, indicating structural validity of the original scale.

3.2.3 Coping styles

The coping styles in this study were based on the Simplified Coping Style Questionnaire (SCSQ) by Xie (1998) in its Chinese version. The questionnaire was adapted and revised to fit the sports context, resulting in a simplified version consisting of 15 items. Examples of the items include "I tend to see the positive side of training or competition outcomes" and "I often fantasize about a miracle happening to change the bad situation." The Likert 7-point scale was used for measurement. Among the items, 11 items measured Positive Coping Strategies (PCS) and 4 items measured Negative Coping Strategies (NCS). The original scale demonstrated reliability and validity, with a Cronbach's α of 0.89 for the internal consistency of the positive coping strategy subscale and a Cronbach's α of 0.78 for the internal consistency of the negative coping strategy subscale. The factor loading values for the first-order model ranged from 0.32 to 0.77, indicate reliability and validity of the original questionnaire.

3.2.4 Athletic performance

Python language was used to extract relevant indicators of the performance of 125 core players from 24 high-level women's basketball teams in the 24th CUBAL (China University Basketball Association) tournament, held from July 14th to July 21st, 2022, through the Game-Log of WeChat Mini Program. The extracted indicators included Personal Total Score (PTS), Minutes (MIN), Rebounds (REB), Offensive Rebounds (OFF), Defensive Rebounds (DFE), Assists (AST), Steals (STL), Blocks (BLK), Field Goal Made (FGM), Three-point Made (3 PM), Free Throw Made (FTM), Turnovers (TO), Fouls (F), and Technical Fouls (TF), totaling 14 indicators. This study conducted reliability and validity tests on the measurement model of athletic performance. The results showed that McDonald's Omega (ω) was 0.83, which met the criteria provided by Peters (2014) for reliability testing, indicating internal consistency of the athletic performance measurement model. Based on factor loading values and Modification Indices (MI), some indicators of athletic performance were removed. In the end, 6 indicators were retained: Personal Total Score (PTS), Minutes (MIN), Rebounds (REB), Steals (STL), Field Goal Made (FGM), and Free Throw Made (FTM). The factor loadings of the revised one-factor model ranged from 0.68 to 0.93. The Composite Reliability (CR) was 0.87, and the Average Variance Extracted (AVE) was 0.57, meeting the criteria provided by Zhang et al. (2020) for convergent validity, indicating convergent validity of the revised indicators.

To test the content validity of athletic performance, a questionnaire was administered to 6 experts (3 high-level basketball coaches and 3 professors in the field) to evaluate the representativeness, rationality, and effectiveness of the 6 indicators. More than half of the experts believed that the Minutes (MIN) may not be positively correlated with athletic performance, and it was deemed unreasonable and therefore excluded from the evaluation. According to the formula provided by Jiang et al. (2011) for expert evaluation, the comprehensive evaluation result was R = 86.74, indicating overall expert evaluation. Additionally, based on the suggestions of two basketball coaches, this study adopted the inverse of the athlete's sports level (ranging from 1 to 5, representing International Elite, National Elite, National Level-1, National Level-2, and no level) to represent the athlete's contribution to the team. These values were multiplied by the weight coefficients and applied to the calculation of athletic performance in relation to 5 indicators, thereby taking into account both the athlete's on-court performance and their performance within the team. This approach yielded more objective and realistic data. The mean score was 6.29 ± 5.23 points, the mean number of rebounds was 3.91 ± 2.58, the mean number of steals was 0.89 ± 0.78, the mean field goal percentage was 0.30 ± 0.17, and the mean free throw percentage was 0.23 ± 0.23.

3.3 Analysis

Due to the sample's self-reported nature, missing values were often present. Statistical analysis revealed that the variable had 0 missing values and 3 (2.40%) incomplete cases. The missing rate was relatively small. The missing data imputation method used in this study was the Expectation Maximization (EM) Imputation. The EM imputation method assumes that the missing data is of the missing at random (MAR) type, and uses the current data information and a specified model to perform the "best guess" for the missing data (Bennett, 2001). This method is suitable for continuous variables. Descriptive statistics, correlation analysis, and structural equation modeling (SEM) were conducted using SPSS 27.0 and AMOS 20.0. The relationship between perfectionistic climate, sources of stress, coping strategies, and athletic performance was examined using Pearson correlation analysis, with *p*-values adjusted for multiple comparisons using the false discovery rate (FDR). There were no missing data in this study. In structural equation modeling (SEM), we aim to reveal linear relationships between variables through the covariance matrix. The accurate estimation of the covariance matrix relies on the data normality. If the data does not follow a normal distribution, it can lead to biased estimates of relationships between variables. Therefore, this study analyzes skewness and kurtosis and assesses whether the data meets the criteria for normal distribution based on the standards outlined by Kline (2016).

The majority of the constructs in this study were measured using self-report data, which may introduce common method bias due to the social desirability effect. Therefore, it is necessary to test for common method bias in the model. Given the large number of items involved in the Perfectionistic Climate Questionnaire-Sport, this study followed the approach proposed by Wu and Wen (2011). The items were first parceled based on the five constructs of the Perfectionistic Climate Questionnaire-Sport, using the latent variable constructs as new indicators. The measurement model of the perfectionistic climate was then simplified using item parcels, and the performance data were standardized before analysis. SEM competes the modeling process through a series of assumptions and constraints. It explores the correlations or causal relationships between variables. By analyzing

correlations among variables, we gain initial insights into their underlying connections and validate the logical coherence of the hypothesized model. Furthermore, conducting validity and reliability analyses is crucial prior to applying SEM. Rigorous assessment of validity and reliability ensures the collected data is dependable and effective, thereby establishing a robust foundation for SEM. Building on this foundation, SEM allows for deeper exploration of relationships between variables, revealing scientific patterns latent within the data and offering robust guidance for practical applications.

In SEM analysis, indices such as χ^2/df, GFI, AGFI, CFI, NFI, and RMSEA were used to assess model fit: (1) χ^2/df should be less than 2; (2) GFI and AGFI should be greater than 0.90; (3) CFI and NFI should be greater than 0.95; (4) RMSEA should be less than 0.06 (Hu and Bentler, 1999; Kline, 2016). Bootstrapping has more statistical power than causal inference and product of coefficients methods for testing indirect effects (Williams and MacKinnon, 2008; Su et al., 2022). Therefore, this study used bootstrapping to test the chain mediation effects of the dual-path model. The significance of the mediating effects was tested using bias-corrected bootstrap methods. Bootstrap resampling was conducted 5,000 times, and if the 95% confidence interval of the bootstrap did not include 0, the parameter estimate was considered significant; otherwise, it was deemed nonsignificant (Preacher and Hayes, 2008). The significance level for all hypothesis tests was set at $\alpha < 0.05$.

Considering that the 125 female basketball starters were nested within 24 high-level teams, a two-level nested data structure was formed. Specifically, the athletes represented the individual level, and the teams represented the group level. Nested data structures can violate the independence assumption at the individual level, potentially leading to interdependence among athletes' perfectionism climate scores within the same team. To examine the independence of the individual-level data, this study applied SPSS 27.0 and HLM 6.08 (Hierarchical Linear Modeling) software to conduct Hierarchical Linear Growth Models analysis and obtained the intraclass correlation coefficients (ICC). The nesting effect (also known as the design effect, Deff) was calculated using the formula $1 + (m - 1) \times ICC$, where m represents the average cluster size. The result showed that Deff = 1.002 < 2, indicating that the nesting effect can be ignored (Muthén and Satorra, 1995).

4 Results

4.1 Descriptive statistics

An analysis of the study sample basic information is presented in Table 1. The survey covered 125 core players from high-level CUBAL women's basketball teams, with an average age of 22.02 ± 1.49 years and an average training period of 8.68 ± 2.21 years. Among them, 43 were national second-level athletes, accounting for 34.40%; 67 were national first-level athletes, representing 53.60%; and 15 were master athletes, making up 12.00%. All athletes were undergraduates: 16 were freshmen, accounting for 12.8%; 26 were sophomores, representing 20.8%; 37 were juniors, making up 29.6%; and 46 were seniors, accounting for 36.8%. The average points scored were 6.29 ± 5.23, average rebounds were 3.91 ± 2.58, average steals were 0.89 ± 0.78, average field goal percentage was 0.30 ± 0.17, and average free throw percentage was 0.23 ± 0.23.

4.2 Common method bias and correlation analysis

A nested competitive model was used to assess the presence of the Common Method Bias. The single-factor Confirmatory Factor Analysis (CFA) yielded $\chi^2 = 1619.91$, $df = 405$, and the multi-factor CFA yielded $\chi^2 = 707.26$, $df = 390$. The difference in degrees of freedom (Δdf) between the two models was 15, with $\Delta\chi^2$ of 912.65 ($p < 0.001$). Thus, this study is not affected by Common Method Bias. As can be seen in Table 2, the absolute values of Skewness in this study range from 0.19 to 0.66, less than 2.00, and the absolute values of Kurtosis range from 0.12 to 1.27, less than 8.00, meeting the testing standards provided by Kline (2016), thus the data in this study can be considered normally distributed. The mean scores of five variables, including perfectionistic climate, sources of stress, and coping methods, range from 3.55 to 5.38, indicating that female basketball players generally have a positive evaluation of the perfectionistic climate, sources of stress, and coping methods. Furthermore, athletic performance is not significantly correlated with perfectionistic climate, sources of stress, and positive coping methods, but it has a significant negative correlation with negative coping methods ($r = -0.26$, $p < 0.001$); significant correlations exist between the rest of the variables with r values ranging from 0.18 to 0.58.

4.3 Reliability and validity analysis

Reliability and validity tests were conducted on six variables: perfectionistic climate, challenge stressors, threat stressors, positive coping, negative coping, and athletic performance. The analysis results are presented in Table 3. Cronbach's α coefficients are all above 0.70, Composite Reliability (CR) values exceed 0.60, and the Corrected Item-Total Correlation (CITC) for each measurement item or indicator are greater than 0.3, indicating that the scale has good reliability (Churchill and Peter, 1984; Hair, 1998; Zhang et al., 2020). In the confirmatory factor analysis, the standardized factor loadings for each measurement item are greater than 0.50, and the calculated Average Variance Extracted (AVE) values for each latent variable are above 0.50, indicating good convergent validity for the latent variables. Moreover, the square roots of the AVE for each latent variable are greater than the correlation coefficients between variables, indicating good discriminant validity for the latent variables (Fornell and Larcker, 1981). A two-way random effects model was used to analyze the intraclass correlation coefficient (ICC), which was 0.77 (95% CI [0.28, 0.46]), and the ICC was greater than 0.75, which, according to the standard set by Pan and Ni (1999), indicates a high degree of consistency in the measurement of the scales of the present study. In summary, the variables selected in this study exhibit good reliability and validity.

4.4 Chain mediation analysis of the model

As shown in Table 4, the results indicate that there is significant indirect effect between perfectionistic climate and challenging stressors, with Z value of 3.01 ($\sigma = 0.14$) and 95% CI [0.16, 0.69], $p < 0.001$. Similarly, there is significant indirect effect between challenging stressors and positive coping strategies, with Z value of

TABLE 1 Analysis of research sample basic information.

Team position	Number	Percentage	Athletic level/ grade	Number	Percentage
Point guard	18	14.4	Master of sports	15	12.0
Shooting guard	10	8.0	National first level	67	53.6
Small forward	26	20.8	National second level	43	34.4
Power forward	19	15.2	Freshman	16	12.8
Center	32	25.6	Sophomore	26	20.8
Guard	12	9.6	Junior	37	29.6
Forward	8	6.4	Senior	46	36.8

TABLE 2 Correlation analysis.

	Skew	Kurtosis	M	SD	1	2	3	4	5
1. Perfectionistic climate	0.19	0.61	4.43	1.11	1				
2. Challenge stressors	−0.66	1.27	5.12	1.06	0.43***				
3. Threat stressors	0.53	−0.12	3.55	1.44	0.58***	0.43***			
4. Positive coping strategies	−0.29	1.57	5.38	0.83	0.21*	0.55***	0.29***		
5. Negative coping strategies	−0.33	0.26	4.42	1.27	0.32***	0.28***	0.45***	0.18*	
6. Athletic performance	0.24	−0.59	-	-	−0.04	0.06	−0.04	0.15	−0.26***

*$p < 0.05$; ***$p < 0.001$.

2.95 ($\sigma = 0.17$) and 95% CI [0.25, 0.93], $p < 0.001$. Furthermore, there is significant indirect effect between positive coping strategies and athletic performance, with Z value of 2.03 ($\sigma = 0.16$) and CI [0.04, 0.68], $p = 0.03 < 0.05$. The chain mediation effect between challenging stressors and positive coping strategies in the relationship between perfectionistic climate and athletic performance is also significant, with Z value of 1.86 ($\sigma = 0.04$) and 95% CI [0.01, 0.17], $p = 0.01 < 0.05$, with effect size $\upsilon = 0.08$. According to the criteria set by Fern and Monroe (1996) as well as Zheng et al. (2011), this chain mediation exhibits a moderate effect size. In summary, challenging stressors mediate the relationship between perfectionistic climate and athletic performance through positive coping strategies. Additionally, there are significant positive correlations between perfectionistic climate and challenging stressors, challenging stressors and positive coping strategies, and positive coping strategies and athletic performance, supporting research hypothesis H1.

There is significant positive correlation between perfectionistic climate and threat stressors, with Z value of 5.01 ($\sigma = 0.18$) and 95% CI [0.57, 1.28], $p < 0.001$. Similarly, there is significant positive correlation between threat stressors and negative coping strategies, with Z value of 3.32 ($\sigma = 0.11$) and 95% CI [0.17, 0.60], $p < 0.001$. On the other hand, there is significant negative correlation between negative coping strategies and athletic performance, with Z value of −2.17 ($\sigma = 0.18$) and 95% CI [−0.81, −0.15], $p < 0.001$. The chain mediation effect between threat stressors and negative coping strategies in the relationship between perfectionistic climate and athletic performance is also significant, with Z value of −1.75 ($\sigma = 0.07$) and 95% CI [−0.38, −0.04], $p < 0.001$, with effect size $\upsilon = 0.14$. According to the standards set by Fern and Monroe (1996) and Zheng et al. (2011), this chained mediation demonstrates a moderate effect size. Based on the above, it can be concluded that there is significant positive correlation between perfectionistic climate and threat stressors, significant positive correlation between challenge stressors and negative coping strategies, significant negative correlation between positive coping strategies and athletic performance. Moreover, threat stressors and negative coping strategies play chain-mediated role between perfectionistic climate and athletic performance. Therefore, research hypothesis H2 is supported.

There is no significant correlation between perfectionistic climate and athletic performance, with Z value of 0.23 ($\sigma = 0.13$) and 95% CI [−0.19, 0.32], $p = 0.80$. This indicates that there is no significant relationship between perfectionistic climate and athletic performance. The dual-path model is a fully mediated model (Figure 2). The model chi-square value can be impacted by sample size, leading to poorer model fit. To address this, the Bollen-Stine p Correction method can be used to adjust the model fit (Zhang et al., 2020). After applying the Bollen-Stine p Correction (Bootstrap 5000), the probability of a significant discrepancy model is 0.027, which is less than 0.05, indicating that the model fit is affected by the sample size. The adjusted model fit indices are as follows: $\chi 2 = 529.03$, $\chi 2/df = 1.33$, GFI = 0.93, AGFI = 0.94, CFI = 0.95, NFI = 0.95, RMSEA = 0.05. These indices indicate a good fit for the mediated model.

TABLE 3 Reliability and validity analysis.

Variable	Item	Significance of parameter test				Reliability			Validity		
						Corrected item total correlation	Item reliability	Internal consistency	Composite reliability	Factor loadings	Average variance extracted
		Unstd.	Standard error	Z	*p*-value	CITC	SMC	Cronbach's α	CR	Std.	AVE
Perfectionistic climate	EXC1	1.000				0.593	0.448	0.814	0.819	0.669	0.534
	EXC2	1.142	0.177	6.448	***	0.498	0.696			0.834	
	EXC3	1.130	0.189	5.978	***	0.533	0.576			0.759	
	EXC4	0.742	0.145	5.117	***	0.534	0.417			0.646	
	CRI1	1.000				0.621	0.401	0.835	0.844	0.633	0.579
	CRI2	1.161	0.159	7.288	***	0.701	0.719			0.848	
	CRI3	1.167	0.159	7.330	***	0.643	0.746			0.864	
	CRI4	0.932	0.150	6.211	***	0.620	0.449			0.670	
	ConT1	1.000				0.662	0.656	0.903	0.906	0.810	0.710
	ConT2	1.093	0.091	12.038	***	0.670	0.803			0.896	
	ConT3	0.758	0.089	8.549	***	0.576	0.490			0.700	
	ConT4	1.148	0.090	12.710	***	0.637	0.889			0.943	
	ANX4	1.000				0.642	0.491	0.853	0.854	0.701	0.598
	ANX3	0.823	0.124	6.651	***	0.589	0.417			0.646	
	ANX2	1.276	0.148	8.645	***	0.576	0.823			0.907	
	ANX1	1.126	0.137	8.224	***	0.583	0.661			0.813	
	ConR4	1.000				0.717	0.537	0.829	0.836	0.733	0.565
	ConR3	1.134	0.131	8.634	***	0.584	0.806			0.898	
	ConR2	0.866	0.112	7.769	***	0.580	0.545			0.738	
	ConR1	0.940	0.147	6.419	***	0.617	0.372			0.610	
Challenge stressors	CS1	1.000				0.532	0.434	0.892	0.893	0.659	0.583
	CS2	1.361	0.179	7.601	***	0.621	0.638			0.799	
	CS3	1.191	0.161	7.393	***	0.555	0.596			0.772	
	CS4	1.481	0.190	7.781	***	0.553	0.679			0.824	
	CS5	1.221	0.162	7.545	***	0.557	0.627			0.792	
	CS6	0.994	0.142	7.010	***	0.547	0.523			0.723	

(Continued)

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TABLE 3 (Continued)

Variable	Item	Significance of parameter test				Reliability			Validity		
						Corrected item total correlation	Item reliability	Internal consistency	Composite reliability	Factor loadings	Average variance extracted
		Unstd.	Standard error	Z	*p*-value	CITC	SMC	Cronbach's α	CR	Std.	AVE
Threat stressors	HS1	1.000				0.529	0.384	0.840	0.845	0.620	0.582
	HS2	1.144	0.171	6.681	***	0.650	0.569			0.754	
	HS3	1.361	0.188	7.222	***	0.584	0.808			0.899	
	HS4	1.247	0.187	6.671	***	0.520	0.566			0.752	
Positive coping strategies	PCS1	1.000				0.571	0.263	0.835	0.853	0.513	0.498
	PCS2	1.186	0.245	4.842	***	0.663	0.365			0.604	
	PCS3	1.158	0.209	5.533	***	0.662	0.610			0.781	
	PCS4	1.065	0.196	5.441	***	0.645	0.566			0.752	
	PCS5	1.250	0.221	5.668	***	0.598	0.687			0.829	
	PCS6	1.197	0.227	5.269	***	0.582	0.496			0.704	
Negative coping strategies	NCS1	1.000				0.591	0.462	0.744	0.801	0.680	0.503
	NCS2	1.081	0.206	5.256	***	0.688	0.551			0.742	
	NCS3	1.151	0.222	5.190	***	0.669	0.563			0.750	
	NCS4	0.816	0.184	4.429	***	0.622	0.436			0.660	
Athletic performance	PTS	1.000				0.543	0.863	0.866	0.869	0.929	0.574
	FGM	0.026	0.003	9.705	***	0.540	0.533			0.730	
	FTM	0.033	0.004	9.064	***	0.538	0.486			0.697	
	REB	0.386	0.040	9.620	***	0.527	0.527			0.726	
	STL	0.110	0.013	8.705	***	0.607	0.460			0.678	

***$p < 0.001$.

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5 Discussion

As a team sport, basketball fosters a team atmosphere vastly different from individual sports focused on personal achievements. While individual skills are crucial in basketball, they are not the sole determinant. Basketball relies on teamwork, where each player contributes unique strengths and roles. These diverse roles collectively form a cohesive unit, highlighting the dual nature of perfectionistic within this team environment. This study posits that whether a perfectionistic climate acts as a facilitator or a barrier to athletic performance largely depends on athletes' cognitive appraisal of stress sources and their coping strategies. The perfectionistic climate on athletic performance has positive and negative predictions. In the positive pathway, a perfectionistic climate can positively predict athletic performance through challenge-related sources of stress and positive coping strategies. Conversely, in the negative pathway, a perfectionistic climate can negatively predict athletic performance through threat-related sources of stress and negative coping strategies.

TABLE 4 Results of the chain mediation test of the dual-path model.

	Point estimation	Product of coefficients		95% CI		*p*-value
		σ	Z	Lower	Upper	
Path						
a1	0.42	0.14	3.01	0.16	0.69	***
b1	0.51	0.17	2.95	0.25	0.93	***
c1	0.32	0.16	2.03	0.04	0.68	0.03
a2	0.90	0.18	5.01	0.57	1.28	***
b2	0.36	0.11	3.32	0.17	0.60	***
c2	−0.39	0.18	−2.17	−0.81	−0.15	***
Hypothesis						
H1	0.07	0.04	1.86	0.01	0.17	0.01
H2	−0.13	0.07	−1.75	−0.38	−0.04	***

Bootstrap 5000; ***$p < 0.001$.

5.1 Interpretation of the positive pathway in the dual-pathway model

Previous scholars (Kahn and Byosiere, 1992; Gilboa et al., 2008) generally believed that sources of stress have predominantly negative effects. However, the empirical results of this study indicate that a perfectionistic climate, as a source of stress, can also have a positive effect on athletic performance if approached with positive coping strategies. The Cognitive Appraisal Theory of Stress particularly emphasizes the individual's cognitive appraisal of stress sources. During the cognitive appraisal stage, individuals subjectively evaluate the potential benefits and losses of a single stress source (Folkman et al., 1986; Hanton et al., 2012) and assess the resources they perceive as available to cope with the stress source (Lazarus and Folkman, 1984). The team environment, by creating work demands and shaping social interaction patterns, can significantly predict the individual's assessment of the stress level of a situation and their response to stress (Bliese and Halverson, 1996; Jiang and Probst, 2016). If athletes believe that the perfectionistic climate of their team can bring potential benefits and that they have sufficient resources to cope, they are more likely to have a positive evaluation of the perfectionistic climate as a stress source. Consequently, they may view the perfectionistic climate as a challenge stressor, thereby eliciting more positive coping responses.

Previous research (Haney and Long, 1995; Smith and Christensen, 1995; Calmeiro et al., 2010, 2014; Gaudreau et al., 2010; Nicholls et al., 2010, 2012; Doron and Gaudreau, 2014; Doron and Martinent, 2016) assessing athletic performance through objective or subjective indicators has found a significant correlation between coping

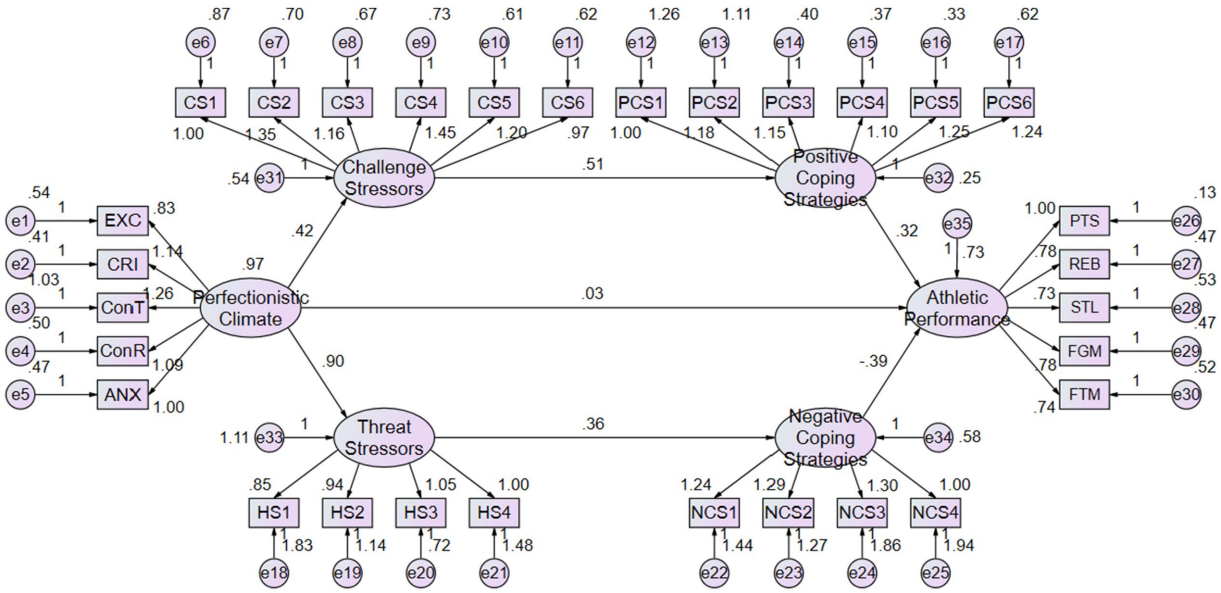

FIGURE 2
Chain-mediated non-standardized test chart of the dual-path model.

strategies and athletic performance. Specifically, positive coping strategies are significantly positively correlated with athletic performance, whereas negative coping strategies are significantly negatively correlated, which is consistent with the findings of this study. And both the positive and negative pathways exhibit moderate effect sizes (Fern and Monroe, 1996; Zheng et al., 2011). When individuals perceive a source of stress as controllable and believe that effort can change the external stress environment, they tend to adopt positive coping strategies. In the Chinese context, organizational discipline within training or competition settings is highly valued, and athletes are expected to obey commands, follow leadership, and consciously adapt to the team atmosphere. Learning to effectively cope with stress sources by enhancing personal capabilities is crucial for improving athletic performance. Lazarus (1993) emphasized that stress and coping strategies interact; stress can stimulate and disrupt coping strategies, while positive coping strategies can reduce the stress perceived from stress sources (Folkman and Lazarus, 1988). When athletes believe they have sufficient abilities and resources to overcome stress sources, the positive pathway towards the perfectionistic climate dual model becomes evident, achieving a new balance between situational demands and individual coping resources. Athletes were better adapt to the perfectionistic climate of the team to meet training and competition requirements. When accustomed to viewing stress sources as challenge stressors, athletes exhibit more positive emotions, more flexible and creative thinking, and are more likely to positively cope with the stress induced by stress sources (Fredrickson, 2001), which also enhances their focus on current training or competition tasks and further improves athletic performance (Gaudreau et al., 2010). Female basketball players of high-level teams who enhance their performance through the positive pathway appear to possess stronger psychological self-regulation capabilities and are better adapted to the perfectionistic climate of the sports team.

5.2 Interpretation of the negative pathway in the dual-pathway model

Competitive sports aim to pursue excellent performance, and the perfectionistic climate as a source of stress is pervasive in training and competition environments, increasing emotional exhaustion and negative physical symptoms in some athletes, leading to decreased training satisfaction and training burnout (Nicholls et al., 2012). According to the research views of Wang et al. (2021), Li and Guo (2021) and Yuan (2022), task-related stress sources enhance athletes' perception of stress, resulting in corresponding attitudes and behaviors. When athletes perceive stress sources as insurmountable and obstructive to their goals, they are more likely to view the perfectionistic climate as a threat stressor. When athletes consider sources of stress uncontrollable and themselves incapable of changing the external environment, they tend to adopt negative coping strategies, through which the perfectionistic climate affects athletic performance via the negative pathway. The perfectionistic climate emphasizes harsh, unreasonable, or even ruthless excessive criticism or punishment of athletes for minor mistakes, or sets rigid and unrealistic expectations, along with stingy recognition or rewards (Grugan et al., 2021). Negative coping is often emotion-centered, manifesting as individuals reducing their negative emotions through avoidance, denial, and other coping strategies (Di et al., 2015). Specifically, it involves efforts to reduce negative emotions cognitively, using avoidance, distancing, or finding positive values in negative events to adjust one's interpretation of stress sources without changing the objective situation (Lazarus and Folkman, 1984). Therefore, athletes who adopt negative coping strategies towards stress sources psychologically distance themselves from the stress sources to mitigate their adverse impacts, showing low enthusiasm for training, negative attitudes, or even avoidance of training.

When athletes face a culture of perfectionism, they may autonomously and continuously adjust their behaviors and cognitions to regulate the affects of this perfectionistic culture within the sports team. When athletes perceive the culture of perfectionism as a stressful event and adopt negative strategies to cope with the pressure, activating the negative towards the avoidant pathway, they struggle to adapt to the perfectionistic culture of the team, hindering their athletic performance. Avoidance, social withdrawal, self-pity, and self-blame, among other negative coping strategies, may temporarily shield athletes from the pressure of the perfectionistic culture and provide brief relief. However, when individuals fail to take proactive coping actions and instead attempt to change uncontrollable environments or resort to avoidance in response to sources of stress, it typically leads to more negative emotions (Crocker and Graham, 1995; Ntoumanis et al., 2015). The emergence of these negative emotions is mainly due to a lack of control over the stressful situation or a lack of direction towards taking direct coping actions (Ntoumanis and Biddle, 1998). Emotion-focused coping strategies tend to result in adverse outcomes (Crocker and Graham, 1995; Ntoumanis and Biddle, 1998; Ntoumanis et al., 1999; Nicholls and Polman, 2007). Coaches need to be particularly vigilant about overt manifestations of negative coping, such as engaging in destructive behaviors that violate organizational norms and undermine organizational interests (Mawritz et al., 2014). Athletes may retaliate against the organization by skipping training sessions or even boycotting them. Literature on competitive sports indicates a significant negative correlation between negative emotions and athletic performance (Lazarus, 1999; Craft et al., 2003; Woodman and Hardy, 2003; Jones et al., 2005), which also effectively explains the negative impact of negative coping strategies on the performance of elite female basketball players.

5.3 The potential pathways through which a perfectionistic affects athletes' performance

Competitive sports often entail pressure, and in the context of a sports team, the perfectionistic climate arises from social interactions between coaches and athletes, as well as among teammates. It represents the extent to which the team environment affects individuals' pursuit of perfect athletic performance, constituting a social stressor. Similar to transformational and empowering leadership styles, as well as high-performance expectations from leaders, these social stressors also exhibit double-edged path predictions. Many studies suggest that these factors can trigger negative emotions, leading to emotional exhaustion, deviant behavior, and interpersonal mistreatment (Jahanzeb and Fatima, 2018; Webster et al., 2018; Jiang et al., 2021; Rosen et al., 2021; Venz and Nesher Shoshan, 2021). However, other research demonstrates that employees may perceive these factors as benign pressure and respond positively to achieve

favorable outcomes (Majeed and Naseer, 2021). Similar to the above social stressors, the perfectionistic climate can elicit both positive and negative responses in athletes, ultimately affecting athletic performance. Different individuals may perceive environmental demands differently, leading to varying stress perceptions and coping responses (Elliott et al., 1994). The affects of perfectionistic climate as a stressor on athletes is not universally harmful, as the extent to which athletes are affected by this stressor varies. The implications of stressors on outcomes depend largely on athletes' cognitive evaluations of the stressor, their perceived resources available for coping with stress, and their coping strategies.

The Stress Cognitive Appraisal Theory particularly emphasizes individuals' cognitive appraisal of stressors and divides it into two processes: primary appraisal and secondary appraisal (Lazarus and Folkman, 1984). Athletes' cognitive appraisal of the perfectionistic climate should also go through these two processes. In the primary appraisal stage, athletes focus on whether and to what extent the perfectionistic climate would affect their well-being. In the secondary appraisal stage, athletes evaluate the characteristics of the stress caused by the perfectionistic climate, consider the feasibility of various coping strategies, the likelihood of potential coping strategies achieving the desired effect, and their own ability to effectively use a certain coping strategy (Lazarus and Folkman, 1984; Folkman et al., 1986). The result of individuals' appraisal of stressors can impact their subsequent coping strategies (Jiang and Wang, 2022). Coping refers to cognitive and behavioral efforts made by individuals to manage specific external and/or internal demands (Folkman et al., 1986). When athletes' evaluation indicates that the perfectionistic climate hinders their well-being and they cannot change the harmful and threatening environmental conditions or resources, they are more likely to adopt negative coping strategies, such as avoidance, distancing, selective attention, and so on. On the other hand, when the evaluation result shows that the perfectionistic climate presents challenges that they can overcome through their efforts or by utilizing available resources, individuals are more likely to use adaptive positive coping strategies, such as redefining problems, generating alternative solutions, and evaluating alternative solutions based on costs and benefits. Both coping strategies can be used to alleviate the harm caused by stressors to individuals and are not inherently good or bad, nor are they mutually exclusive. They reflect different effects of different appraisal results on individuals' responses (Folkman, 1982). However, athletes can positively impact their athletic performance through the mastery path, whereas the harm path negatively affects athletic performance.

The Stress Cognitive Appraisal Theory points out the individual and environmental factors that impact cognitive appraisal and coping strategies (Lazarus and Folkman, 1984). Individual factors impact athletes' understanding of stressors, which subsequently affects their stress responses and coping efforts. These individual factors mainly include commitment and belief (Jiang and Wang, 2022). Commitment refers to what matters to the individual and holds significance, while belief represents an individual's confidence in mastering specific situations, both of which impact athletes' appraisal and coping with the perfectionistic stressor. Moreover, the evaluation and responses of the same individual in different stressful situations may vary, indicating that the context is also an important factor influencing cognitive appraisal and coping strategies (Lazarus and Folkman, 1984). The coach is a key figure responsible for shaping the extent to which athletes experience an environment that is perfectionistic. The role of the coach and specific coaching practices as key sources of pressure to be perfect are also heavily emphasized in theory relating to the development of perfectionism in sport (Appleton and Curran, 2016). The strongest empirical support in this regard is for the role of unrealistic coach expectations and harsh coach criticism with numerous studies showing positive relationships between these coach behaviors and perfectionism in athletes (Sagar and Stoeber, 2009; Gotwals, 2011; Madigan et al., 2019). Aside from traditional mainstream, overt factors such as variance in coaching ability, player talent, and critical in-game decisions, researchers have shown that team dynamics, which is often less perceptible, may also impact performance (Heuzé et al., 2006). Overall, individual and situational factors are interdependent and jointly affects athletes' cognitive evaluations and coping strategies regarding the perfectionistic climate. These factors act as potential moderators, influencing the strength or direction of the sharp path and harm path.

6 Conclusion

Regarding the perfectionistic climate as a stressor in sports settings, if coaches can facilitate athletes to make reasonable cognitive appraisals, the moderate pressure generated by the perfectionistic climate can be perceived as a pleasant and satisfying experience, presenting a positive challenge. This, in turn, leads athletes to cope positively with the pressure, promoting their competitive performance. Conversely, if athletes' cognitive evaluations of the perfectionistic climate deviate, transforming it into a threatening stressor, it may lead to excessive pressure without effective coping strategies. As a result, athletes may experience adverse reactions, such as depleting potential energy reserves and dysregulating adaptive mechanisms, thereby affecting their competitive performance.

The stressor of the perfectionistic climate in sports settings is not always disadvantageous; if coaches can guide athletes to have reasonable appraisals, stress can be transformed into motivation. On one hand, enhancing athletes' capacity to handle pressure is fundamental to their ability to cope with competitive stress. Therefore, during training, coaches can expose athletes to continuous stressor stimuli, leading to biological adaptations that improve athletes' ability to adapt to organizational environments and cope with pressure. Simultaneously, guiding athletes to understand and perceive excessive expectations from their surroundings will facilitate their growth along the mastery path. On the other hand, coaches can help athletes set challenging goals to unleash their potential. By fostering organizational commitment, enhancing athletes' psychological capital, and boosting self-efficacy, coaches can help athletes break free from self-imposed limitations, leading to greater improvement and better performances in sports.

7 Limitations and future

This study measured multiple key variables, including perfectionistic climate, stressors, coping strategies, and athletic performance. While objective evaluations were used for assessing athletic performance, the remaining constructs were measured through subjective self-reports. The results reported by individuals

may be influenced by factors such as social desirability bias, coach leadership styles, and impression management. Future research could consider using modern instruments to collect objective data for standardized measurements of elements related to the dual-path model. For instance, when assessing individuals' cognitive appraisals of stressors, collecting relevant information from training diaries could be employed to measure their stress coping strategies effectively. The use of advanced scientific methods can provide more accurate verification of the relationships between elements of the dual-path model, enabling better application and generalization of the theory in other sports domains.

Additionally, although this study employed multilevel linear growth modeling to analyze the independence of individual-level data within the nested data structure, the data were collected only from core players of the top 24 women's basketball teams in the 24th edition of CUBAL in 2022. Given the limited number of teams in the study, the absence of nested effects may be specific to this dataset. Future research should consider investigating the influence of individual-level and team-level factors on each other in order to obtain a more comprehensive understanding of the phenomenon. In future research, it may still be necessary to consider the mutual effects between individual-level and team-level factors. Recent research by González-García et al. (2023) has found that improving the quality of coach-athlete relationships, including closeness, commitment, and complementarity, can optimize precompetitive task-oriented coping and the intensity of positive affect before competitions, thereby promoting athlete satisfaction and goal attainment. This also serves as a reminder that individual and situational factors are interdependent and jointly influence athletes' cognitive evaluations and coping strategies regarding the perfectionistic climate. These factors act as potential moderators, influencing the strength or direction of the sharp path and harm path.

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 the authors hereby declare that all methods were carried out in accordance with relevant guidelines and regulations. The Academic Ethics Committee of the School of Physical Education and Sport, Beijing Normal University, approved the research protocol of this study (BNUCPES0021). Informed consent was provided by the participants. 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

MM: Conceptualization, Formal analysis, Funding acquisition, Investigation, Project administration, Writing – original draft, Writing – review & editing. R-HS: Conceptualization, Data curation, Investigation, Writing – original draft, Writing – review & editing. KK: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. R-RZ: Conceptualization, Formal analysis, Writing – original draft. LC: Conceptualization, Formal analysis, Investigation, Writing – original draft. WW: Conceptualization, Data curation, Investigation, Writing – review & editing. WL: Conceptualization, Writing – review & editing. M-CH: Conceptualization, Data curation, Formal analysis, 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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Effects of fancy rope-skipping on motor coordination and selective attention in children aged 7–9 years: a quasi-experimental study

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Introduction: Recent studies have emphasized the intricate connection between exercise and cognition, focusing on specific cognitive processes and their correlations with specific motor skills. However, research on the impact of the qualitative aspects of movement on both short- and long-term cognitive performance is limited. In this quasi-experimental study, we investigate the impact of a 10-week fancy rope-skipping intervention on motor coordination and selective attention of 7–9-year-old children.

Methods: A total of 60 primary school students from Changbin School in Haikou participated and completed the study from October to December 2022. The 60 participants were divided into a fancy rope-skipping group and a control group. Children's motor coordination was assessed using the Körperkoordinations Test für Kinder (KTK), while selective attention was evaluated using the d2 Test of Attention. Children were assessed at baseline and after the 10-week intervention.

Results: Compared with the control group, the scores for the total KTK and for the hopping for height, jumping sideways, and moving sideways sub-items were significantly higher in the rope-skipping group after the intervention, with a significant interaction effect between time and intervention. Attention concentration improved in the rope-skipping group and had a significant interaction effect between time and intervention compared with the control group; the effects of the intervention on other aspects of selective attention were unclear.

Conclusions: Our study suggests that a 10-week fancy rope-skipping intervention may potentially enhance motor coordination and selective attention accuracy in children aged 7–9 years.

KEYWORDS

jump rope, primary school children, cognitive skills, motor skills, d2 Test of Attention, Körperkoordinations Test für Kinder

1 Introduction

Fostering cognitive skills is crucial for children's academic success and overall developmental wellbeing. Selective attention is of particular importance, as a cognitive mechanism that adeptly filters pertinent information while inhibiting interference. Isbell et al. (2017) considered selective attention as a "multiplier" that can significantly influence various cognitive domains, and it is a foundational capacity connected to a range of

cognitive abilities and academic success (Páez-Maldonado et al., 2020). Deficits in selective attention have been associated with learning difficulties and behavioral problems in the classroom (Mueller et al., 2017). Research suggested that selective attention stabilizes around the age of 7 and continues to develop throughout ages 8 or 9 (Plebanek and Sloutsky, 2019; Phelps et al., 2022). Training can enhance selective attention (Itthipuripat et al., 2017), highlighting the importance of exploring interventions to improve it in children.

Previous studies have suggested that exercise has a close association with various aspects of cognition (Biddle et al., 2019). A recent systematic review proposes that physical activity is beneficial for cognitive improvement in children and adolescents, and that extracurricular physical education interventions and programs that increase physical activity are the most effective (Álvarez-Bueno et al., 2017). Motor and cognitive skills may share a similar neural basis, with co-activation between the prefrontal cortex, cerebellum, and basal ganglia during some motor and cognitive tasks (Middleton and Strick, 2000). Further, motor and cognitive skills share cognitive processes. Exercise can enhance brain functioning and promote neural plasticity, which may lead to improvements in attentional control (Best, 2010). Additionally, exercise has been found to increase the levels of neurotransmitters, such as dopamine, which are associated with attention and executive functioning (Chang et al., 2012). Children may also experience parallel developmental stages in motor and cognitive skills, with overlapping developmental schedules that accelerate between the ages of 5 and 10 years (van der Fels et al., 2015). However, given the broad domains encompassing both motor skills and cognitive abilities, there is no consensus on this correlation, and recent studies have highlighted an intricate relationship between specific cognitive processes and particular types of motor skills.

Some studies find that the motor dimensions most closely related to cognitive performance are motor coordination (Vojtíková et al., 2023). Motor coordination is a complex collaborative process involving the nervous and musculoskeletal systems. Its core component reflects the degree of body control, which is the basis for learning and mastering motor skills (Vandorpe et al., 2012). van der Fels et al. (2015) proposed that complex motor skills such as fine motor skills, coordinated movements, and sequential movements should be incorporated into motor intervention programs to stimulate motor and higher-order cognitive skills in prepubertal children. Moreover, complex sports, such as ball games, pose more challenges to motor coordination and cognitive processes (Moratal et al., 2020). Howard (2023) also suggests that the focus of attention significantly influences motor coordination.

Fancy rope-skipping is also a physical activity that involves performing a variety of complex and rhythmic jump rope movements that may demand high levels of motor coordination and cognitive processing (Lorke et al., 2022; Burdack and Schöllhorn, 2023). Many studies found that jumping rope has a positive impact on children and adolescents' physical fitness, such as speed, flexibility, strength, coordination (Barrio et al., 2023; Zhao et al., 2023). While research has explored various physical activities' effects on children's development, limited studies have specifically investigated the impact of jumping rope on motor coordination and attention in children aged 7–9 years. We hypothesize that a 10-week intervention involving fancy rope-skipping could significantly enhance both motor coordination and selective attention abilities in this age group. To test this hypothesis, our study aims to assess the effects of the intervention on motor coordination and selective attention performance in school-aged children using the Körperkoordinations Test für Kinder (KTK) and the d2 Test of Attention, respectively.

2 Methods

2.1 Participants

Following a previous study (Delin et al., 2019), WinPepi software was used to calculate the sample size for a 5% significance level, 80% statistical power, 95% confidence level, and 10% dropout rate; the minimum required sample size was determined to be 50 individuals. Given the potential risk of withdrawal during the pandemic, a total of 60 individuals were recruited as study participants, with 30 allocated to the fancy rope-skipping group and 30 to the control group. These participants were primary school students aged 7–9 years at Changbin Primary School in Haikou City, Hainan Province, China.

The fancy rope-skipping group was selected from students who enrolled in the fancy rope-skipping course after-school program, with inclusion criteria including: (1) healthy children aged 7–9 years without significant illnesses or disabilities, who could participate in fancy rope-skipping activities; (2) those who had not previously received fancy rope-skipping training. The inclusion criteria for the control group were as follows: (1) healthy children aged 7–9 without attend the fancy rope-skipping training; and (2) able to consistently attend physical education. Exclusion criteria included: (1) students participating in other after-school physical education training courses (2) students participating in courses related to improving motor coordination and selective attention; and (3) children with attention deficit disorders, neurological and developmental disorders, and reading difficulties.

In addition to their regular academic activities, the rope-skipping group received 10 weeks of fancy rope-skipping training as an after-school program, whereas the control group did not participate in a similar exercise training program.

2.2 Study design and procedure

This quasi-experimental study was conducted at Changbin Primary School, Haikou, Hainan Province, China, between October 2022 and December 2022.

2.2.1 Procedure

Under the condition that the basic daily curriculum of the fancy rope-skipping group aligns with that of the control group (comprising 32 cultural classes and three physical education classes

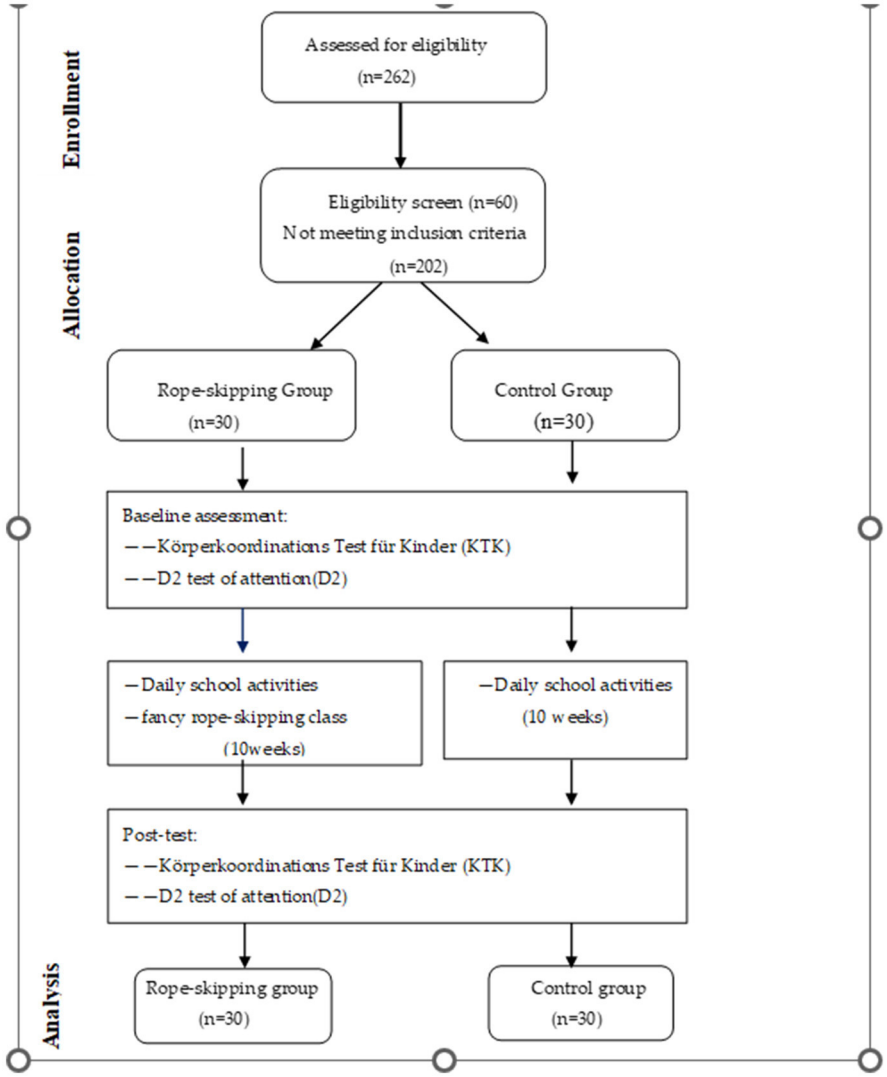

FIGURE 1
Study procedure.

per week), the fancy rope-skipping group participates in after-school sessions delivered by professional coaches from the Fancy Rope-Skipping Association on Monday and Wednesday afternoons from 5:00 to 6:00 p.m. These sessions are led by a head professional coach and supported by two teaching assistants, all of whom have undergone standardized training in fancy rope-skipping courses organized by the State Sports Administration. They have obtained certification as fancy rope-skipping coaches and have accumulated over 2 years of experience in teaching fancy rope-skipping. The control group maintained regular study routines without intervention. Motor coordination and selective attention were measured before and after the intervention (Figure 1). The tests were conducted by graduate students who had received specialized training, and all tests were completed within 1 week.

2.2.2 Intervention

The rope-skipping program content was based on Level 1 exercises developed by the Chinese sports agency (Social Sports Guidance Center, 2021) and involved eight instructional exercises: left-right rope swing, double-footed single swing jump, double-footed bicycle jump, jumping jack rope skipping, bow step rope skipping, double-footed left-right rope skipping, basic crossover rope skipping, foot hook ground tap rope skipping, and knee lift rope skipping (Table 1). From the setting of eight teaching contents to the teaching process, we adhere to the principles of progression and differentiated instruction. For instance, in the first lesson, we introduced the basic classroom requirements, the background knowledge of the fancy rope-skipping jump, the equipment of the jump rope, the proper rope length adjustment, and the grasping skills, then focus on learning to use wrist rotation to swing the rope from side to side and practice this coordination with music. In the second lesson, we focus on learning double-footed rope skipping. The instructional process unfolds as follows: firstly, a review of the left-right rope swing from the previous lesson; subsequently, instruction on basic stance, takeoff and landing movements, and stationary double-footed jumps (without a rope) until achieving 10–50 synchronized jumps with music. Next, participants engage

TABLE 1 The main content of the fancy jump rope course.

Weekly	Sessions	Teaching Content	Teaching process and requirements
1st	1	Left-right rope swing: swing the rope from behind to the front with both arms, swinging the rope to the right side of the body without passing it over the feet; then swing the rope to the left side of the body, with a one-beat-one-movement rhythm. Repeat this sequence on both sides four times to complete the left-right rope swing exercise	(Five sets of 8–10 rep): practice 8–10 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
	2	Double-footed single swing jump: hold the rope handle with both hands and swing the rope forward, keeping both feet parallel with a slight gap, jump over the rope, and the rope should make one full circle around the body. Complete the double-footed single swing jump exercise with a one-swing-one-jump rhythm	(Five sets of 5–10 rep): practice 5–10 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
2nd	3	Review the previous content	Reviewing left and right rope swinging and jumping rope with both feet. Phase 1, (two sets of 10–15 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round. Phase 2, (two sets of 10–15 rep): connected two movement, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round.
	4	Double-footed bicycle jump: start in a stationary double-footed standing position, hold the rope handle with both hands, swing the rope forward once, and then lift each foot one after the other to jump over the rope. Children need to continuously alternate jumping over the rope with each foot, maintaining a one-swing-one-jump rhythm. Repeat this sequence on both the left and right sides four times to complete the double-footed bicycle jump exercise	(Five sets of 4–8 rep): practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
3rd	5	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round. Phase 2, (two sets of 8–10 rep): connected three movements, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round.
	6	Jumping jack rope skipping: start in a static, double-footed standing position, hold the rope handle with both hands, and swing it forward. When both feet are in the air while clearing the rope, quickly spread them apart as they descend, with knees slightly bent to cushion the landing. When the rope makes its second quick contact with the ground, bring both feet together in the air while clearing the rope. Maintain a one-beat-one-movement rhythm to complete the Jumping Jack rope skipping exercise	(Five sets of 4–8 rep): practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
4th	7	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round. Phase 2, (two sets of 8–10rep): connected four movements, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round.
	8	Bow step rope skipping: start in a static, double-footed standing position, hold the rope handle with both hands, and swing it forward. When both feet are in the air while clearing the rope, quickly spread them apart into a front-back bow step motion as they descend. When the rope makes its second quick contact with the ground, bring both feet back together to jump over the rope. Maintain a one-beat-one-movement rhythm, and repeat the bow step motion four times on both sides to complete the Bow Step rope skipping exercise.	(Five sets of 4–8 rep): practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
5th	9	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round. Phase 2, (two sets of 8–10 rep): connected five movements, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 15-s rest between round.

(Continued)

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TABLE 1 (Continued)

Weekly	Sessions	Teaching Content	Teaching process and requirements
	10	Double-footed left-right jump: start in a static, double-footed standing position, hold the rope handle with both hands, and swing it forward. When both feet are in the air while clearing the rope, quickly bring them together and land to the right. On the next rope clearance, jump to the left. Maintain a one-beat-one-movement rhythm, and repeat this sequence four times on both the left and right sides to complete the Double-Footed Left-Right Jump exercise	(Five sets of 4–8 rep): practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
6th	11	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round. Phase 2, (two sets of 8–10 rep): connected six movements, 10–15 perfect rep, stop, rest 10 s and reset. Two rounds, and a 25 s rest between round.
	12	Basic Cross-Jumping: start with a static and stand on your feet, hold the rope handle with both hands and shake the rope, this action is divided into two beats to complete, the first beat of both hands for the straight shake the rope, the second beat needs to be changed to cross the rope for the change of the two hands, the rhythm of a beat and a move, the two beats were repeated four times, to complete the basic cross-jumping exercises.	(Five sets of 4–8 rep): practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
7th	13	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round. Phase 2, (two sets of 8–10 rep): connected seven movements, 10–15 perfect rep, stop, rest 10 s and reset. Two rounds, and a 25 s rest between round.
	14	Foot hook ground tap jump: start in a static, double-footed standing position, hold the rope handle with both hands, and swing the rope. In this exercise, while one foot hooks and taps the ground forward, the other foot jumps straight over the rope. Then, on the next rope clearance, alternate and perform the same action. Maintain a one-beat-one-movement rhythm, and repeat this sequence four times with both the left and right feet to complete the Foot Hook Ground Tap Jump exercise.	(Five sets of 4–8 rep): Practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
8th	15	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round. Phase 2, (two sets of 8–10 rep): connected eight movements, 10–15 perfect rep, stop, rest 10 s and reset. Two rounds, and a 25 s rest between round.
	16	Knee lift jump: start in a static, double-footed standing position, hold the rope handle with both hands, and swing the rope. When both feet are in the air while clearing the rope, lift one knee forward while the other foot jumps straight over the rope. On the next rope clearance, alternate and perform the same action. Maintain a one-beat-one-movement rhythm, and repeat this sequence four times with both the left and right feet to complete the Knee Lift Jump exercise.	(Five sets of 4–8 rep): practice 4–8 perfect rep, stop, rest 5 s and reset. Five rounds, and a 15-s rest between round.
9th	17	Review the previous content	Phase 1, (two sets of 8–10 rep): practice each movement, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round. Phase 2, (two sets of 8–10 rep): connected night movements, 10–15 perfect rep, stop, rest 10 s and reset. Two rounds, and a 25 s rest between round.
	18	Intensive and sequential practice of the first five exercises	Phase 1, (two sets of 8–10 rep): practice previous four movements, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round. Phase 2, (two sets of 8–10 rep): connected night movements, 10–15 perfect rep, stop, rest 10 s and reset. Two rounds, and a 25 s rest between round.
10th	19	Intensive and sequential practice of the last four exercises	Phase 1, (two sets of 8–10 rep): Practice last five movements, respectively, 10–15 perfect rep, stop, rest 5 s and reset. Two rounds, and a 20-s rest between round. Phase 2, (two sets of 8–10 rep): connected night movements, 10–15 perfect rep, stop, rest 10 s and reset. Two rounds, and a 25 s rest between round.
	20	To demonstrate a simple creative rope skipping routine	Five-min preparation time, draw lots by group to show the pattern rope skipping simple creation routine, 30 s—1 min.

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in 100 jumps using a cordless jump rope before transitioning to rope skipping, practicing repetitively until proficiency is achieved. We emphasize the coordination of upper body rope swinging with lower body jumping to achieve rhythmic synchronization. Individualized goals are established based on student progress, with the foundational target of completing consecutive double-footed jumps 10 times or more. Each session lasted 60 min and consisted of a 15-min warm-up phase, followed by 35 min of continuous moderate-to-high-intensity physical activity (including the study and practice of rope skipping movements, as well as 5–10 min of basic physical fitness exercises). The session concluded with 10 min of cool-down and stretching exercises. In each class, the learning of rope skipping movements involved explanations of key points such as body posture, jumping timing, wrist movement, hand-foot coordination, breath control, and rhythm. Intensity was monitored by the coach through the Borg rating of perceived exertion (13–14, somewhat hard) (Borg, 1982; Yunting et al., 2017).

2.2.3 Outcome measures

- Motor Coordination Measurement. The KTK was developed in Germany in 1974. It is a standardized assessment tool designed to evaluate and measure the motor coordination skills of children aged 5–14 years old (Kiphard and Schilling, 1974). It has been used and showed good reliability and validity worldwide (Vandorpe et al., 2011; Moreira et al., 2019), including in studies on Chinese children (Song, 2020). The KTK demonstrates a good test-retest reliability (0.76–0.85), which is similar to Li et al.'s (2023) study. The KTK assessment was conducted in this study and its scoring adhered to the guidelines provided in the manual (Kiphard and Schilling, 2007), which are outlined below.

(1) Walking backwards: Participants were instructed to walk backward on three different wooden planks, which were 5 cm above the ground and 3 m in length, with widths of 6, 4.5, and 3 cm, respectively. Scoring was determined based on the total number of backward steps.
(2) Hopping for height: Using 60 × 20 × 5 cm foam mats as obstacles, participants were directed to execute one-legged jumps with the objective of clearing the foam mats while landing on the same foot. Scoring was determined based on the number of successfully cleared foam mats and the total number of attempts.
(3) Jumping sideways: On a 100 × 60 cm rectangular wooden board divided into two equal sections by a 60 × 4 × 2 cm obstacle placed in the center, participants performed lateral two-legged jumps from side to side. The objective was to tally the number of jumps completed in a 15-s window, with two attempts granted. The final score was derived by adding the scores of both attempts.
(4) Moving sideways: Participants were instructed to stand on one side of a divided wooden board with an obstacle, and their task was to perform sideways movements by lifting one foot at a time and placing it on the opposite side of the obstacle. The test measures the number of lateral movements completed in a 20-s timeframe, with two attempts. This score was added twice. Finally, the overall results were added to the four sub-item results.

- Selective attention measurement. The d2 Test of Attention is a widely used psychological assessment tool designed to measure selective attention and concentration (Brickenkamp and Zillmer, 1998). The scale exhibits high reliability and validity, it showed good test-rest reliability (0.80–0.91), as similar to previous research (Lee et al., 2018). The d2 Test of Attention consists of a grid containing 14 rows and 47 columns housing 658 characters. These characters are composed of four types: "d," "b," "p," and "q." Each of these characters is accompanied by zero, one, or two short vertical dashes or dots above, below, or above and below them ($'$, $''$). During the test, participants were instructed to find and mark, within a maximum of 20 s for each row, the characters in each row that had two vertical dashes or dots above them, while ignoring all other characters.

The scale has five dimensions calculated based on the foundation parameters of the total number of items (TN), *attention concentration (TN-E),* concentration performance (CP), *the error percentage (E%), and the fluctuation rate (FR)*. Regarding dimensions, the first is TN, which denotes the total number of characters processed within a specified time, including correct responses, omissions, and errors. The second is a TN-E, which is the total number of symbols per row minus the total number of errors [E = E1 + E2, errors of omission (E1), errors of commission (E2)]. The third is CP, which is the total number of correct responses minus E2. The fourth is the E%, which is the percentages of E1 and E2 within the TN in a row. Finally, the FR refers to the variance between the highest and lowest counts of tagged characters.

2.3 Statistical analysis

Data were analyzed using SPSS Statistics version 26.0 (IBM). The Shapiro–Wilk test was used to assess the normal distribution, and the diverse evaluation parameters were represented as mean ± standard deviation (M + SD). A 2 (rope-skipping and control groups) × 2 (baseline and after 10 weeks) mixed-model ANOVA was used to evaluate the impact of the intervention on the KTK and d2 Test of Attention scores. The simple main effects of time were analyzed to demonstrate the mean change in scores over the 10 weeks for each group. The changes observed across these 10 weeks were subsequently presented as a percentage change (% Δ). The effect size for the interaction effect was assessed using partial eta square (ηp^2), with values categorized as small (0.01), medium (0.06), and large (0.14) (Lakens, 2013). Statistical significance was set at a $p < 0.05$.

3 Results

Participants' demographic characteristics are shown in Table 2.

3.1 Comparison of KTK scores after interventions

The results showed that KTK total scores were significantly higher in the rope-skipping group (% $\Delta = 8.29$, $p < 0.001$) than in the control group (% $\Delta = 1.89$, $p < 0.001$) after the 10-week intervention. Additionally, there was a significant interaction effect between time and the intervention [$F_{(1,58)} = 7.931$, $p = 0.007$, $\eta p^2 = 0.12$, medium]. Similar changes were observed in the hopping for height, jumping sideways, and moving sideways. A comparison of the scores for the KTK individual items between groups is presented in Table 3.

3.2 Comparison of d2 scores after interventions

When comparing the changes in d2 scores between the two groups after the 10-week intervention, we found that E% and FR decreased significantly in the rope-skipping group, while the control group showed no significant changes. The CP score improved significantly in the rope-skipping group; however, the changes in the control group were not significant. However, the difference between the two groups was only significant in the TN-E category, and we observed a significant interaction effect between time and the intervention [$F_{(1,58)} = 4.421$, $p = 0.004$, $\eta p^2 = 0.071$, medium]. A comparison of the scores by group for the d2 Test of Attention individual items is presented in Table 4.

TABLE 2 Demographic characteristics of the two groups.

	Rope-skipping group	Control group
Age (Mean ± SD)	8.07 ± 0.69	8.03 ± 0.85
Sex		
Male *n*, (%)	10 (33.3%)	11 (36.7%)
Female *n*, (%)	20 (66.7%)	19 (63.3%)
Height	127.23 ± 4.86	127.50 ± 6.56
Weight	25.30 ± 6.56	24.00 ± 3.82
BMI	15.52 ± 2.10	14.69 ± 1.52

4 Discussion

This study evaluated the effectiveness of a 10-week fancy rope-skipping intervention on motor coordination and selective attention in 7–9-year-old children. Compared to the control group, the rope-skipping group showed significant improvements in overall motor coordination scores, as well as in specific aspects such as hopping for height, jumping sideways, and moving sideways. Regarding the d2 test measures, in the control group, no significant improvements were observed after the intervention, whereas the rope-skipping group demonstrated improvements in E%, CP, and FR compared to the baseline. Still, only the TN-E category showed a change in the rope-skipping group that was significantly higher than that of the control group. These findings indicate that our 10-week fancy rope-skipping intervention may potentially enhance the development of motor coordination in children aged 7–9 years. Furthermore, the intervention seems to influence attention accuracy; however, its effects on other aspects of selective attention remain uncertain.

Motor coordination involves a series of brain processes, including sensory input, perceptual and cognitive processing, and motor production, all of which work together to achieve precise and coordinated movements (Iorga et al., 2023). Fancy rope-skipping

TABLE 3 The KTK scores at pre- and post-test for the rope-skipping and control groups.

Outcome	Pre-test	Post-test	% Δ	A group-by-time interaction effect		
Group	Mean ± SD	Mean ± SD		$F_{(1,58)}$	*p*	Partial η^2
Walking backwards						
RSG	35.97 ± 12.21	35.50 ± 9.63	−1.31	0.161	0.69	0.003 (very small)
CON	40.20 ± 8.96	40.70 ±8.21	-1.24			
Hopping for height						
RSG	42.90± 12.86	48.73 ± 10.89	13.59**	5.79	0.019*	0.091 (medium)
CON	42.87 ±10.67	44.53 ± 6.85	3.87			
Jumping sideways						
RSG	45.03 ± 5.62	49.93± 5.63	10.88**	11.809	0.001*	0.169 (large)
CON	43.37 ± 5.04	43.77 ± 4.70	0.92			
Moving sideways						
RSG	15.23 ± 2.13	16.50 ± 1.55	8.33*	5.678	0.02*	0.089 (medium)
CON	14.80 ± 2.04	14.90 ± 1.42	0.68			
Total score						
RSG	139.13 ± 26.81	150.67 ± 20.59	8.29**	7.931	0.007*	0.120 (medium)
CON	141.23± 16.31	143.90 ± 12.62	1.89**			

RSG, rope-skipping group; CON, control group.
*$p < 0.05$, **$p < 0.01$.

TABLE 4 The d2 test scores at pre- and post-test for the rope-skipping and control groups.

Outcome	Pre-test	Post-test	% Δ	A group-by-time interaction effect		
Group	Mean ± SD	Mean ± SD		$F_{(1,58)}$	p	Partial η^2
TN						
RSG	623.53 ± 61.63	650.17± 21.68	4.33	3.465	0.068	0.056 (small)
CON	636.07 ± 42.28	632.37 ± 37.52	−0.63			
TN-E						
RSG	580.90 ± 64.28	614.80 ± 31.84	5.86	4.421	0.040*	0.071 (medium)
CON	593.80 ± 46.44	591.77 ± 42.98	−0.34			
E%						
RSG	6.90 ± 3.25	5.47± 2.96	−20.72**	3.014	0.088	0.049 (small)
CON	6.68 ± 2.28	6.48 ± 2.21	−2.99			
CP						
RSG	53.37 ± 20.34	60.63 ± 18.60	13.60**	1.778	0.188	0.030 (small)
CON	53.73 ± 13.69	55.40 ± 12.81	3.12			
FR						
RSG	6.17 ± 2.17	4.93 ± 1.72	−20.09*	2.870	0.096	0.047 (small)
CON	5.83 ± 1.80	5.57± 1.41	−4.50			

RSG, rope-skipping group; CON, control group.
*$p < 0.05$, **$p < 0.01$.

typically involves a variety of complex rope-skipping movements that incorporate changes in posture and jumps, such as single swings, double swings, leg hooks, knee raises, and other transitions. That is, it is a physical activity that requires highly coordinated movements of the upper and lower body muscles to regain balance and propulsion, while synchronizing with the rhythm of the music and the rope swing. In this study, improvements in motor coordination, such as hopping for height, were assessed in relation to the coordination of the lower limbs and to explosive power. From a muscle contraction perspective, rope jumping is considered a stretch-shortening cycle exercise, which is a key physiological process for generating explosive power and rapid movements (Miyaguchi et al., 2014). During a stretch-shortening cycle, muscles are stretched and quickly shortened, releasing stored elastic energy to produce a significant force. This process involves neural control and coordination to ensure that muscle fibers shorten at the appropriate time for the desired movement and force production (Aeles and Vanwanseele, 2019). Chen and Wu (2022) showed that 8 weeks of rope-skipping training can improve lower limb coordination and strength, and enhancing standing long jump performance in male college students. A systematic review found that compared to regular physical education classes, jump rope exercises resulted in better improvement of coordination in preadolescent girls (Zhao et al., 2023).

Regarding the procedures in the KTK assessment, the jumping sideways procedure reflects coordination and explosiveness during lateral jumps, while the moving sideways procedure assesses coordination and flexibility during lateral movements. The observed improvements in these measures suggest an association between the 10-week fancy rope-skipping training and improvements in children's coordination and stretch-shortening cycle capabilities. These findings align with those in a past study, wherein 8 weeks of rope-skipping exercises in soccer training enhanced overall motor coordination in preadolescent soccer players (Trecroci et al., 2015). However, the improvement in backward walking was not significant, possibly because the primary focus of the fancy rope-skipping content in this study was on forward and lateral jumping movements, which emphasize forward and lateral balance and coordination. Conversely, backward walking places a stronger emphasis on reverse movement control.

Prior research has suggested that complex exercise intervention programs can be utilized to stimulate both the physical and higher-order cognitive skills of pre-adolescent children (Greco et al., 2023). Fancy rope-skipping involves a wide range of movements and techniques, ranging from basic single jumps to more complex maneuvers such as crossovers and rotations. These movements require flexibility in switching and adjusting between them, as well as active cognitive engagement. The d2 Test of Attention assesses an individual's ability to concentrate attention and make rapid and accurate target identifications and markings when faced with distracting information (Gutiérrez-Hernández et al., 2021). Thus, it reflects visual perception speed and concentration abilities and is not related to intelligence. In this study, the rope-skipping group exhibited a significant decrease in E% and FR after the intervention. A lower E% generally indicates higher attentional accuracy, while a lower FR suggests that an individual can maintain their focus more consistently. The significant improvement in the CP index in the rope-skipping group indicates an enhanced ability to maintain focus within a limited timeframe. Meanwhile, in the control group, the changes in these indicators were not significant.

When comparing groups, the significant increase in TE-E reflected better attention performance in the children concerning target identification and marking. A similar study by Buchele Harris et al. (2018) examined the effects of daily 6-min coordinated-bilateral physical activity breaks over a 4-week period in fifth-grade students and found that the intervention significantly increased TN, TN-E, CP, and FR.

However, there has been relatively limited research on the effects of exercise interventions on selective attention, and most related studies have focused on the immediate effects of these interventions. Research by Ligeza et al. (2023), demonstrated that a single session of vigorous-intensity exercise improved neural processing related to selective attention. Meanwhile, Altermann and Gröpel (2023) found that moderate-to-high-intensity endurance, strength, and coordination exercises lasting 25 min each led to similar improvements in selective attention, and that coordination exercises did not show a distinct advantage. It was speculated that these similar improvements across exercises may be due to the longer duration and greater intensity of these exercises, which generally elevate brain activity levels (including prefrontal cortex structures) and make changes evoked by the exercise no longer closely tied to the complexity of the exercise, but rather related to increased brain oxygenation and activation. Guillamón et al. (2021) found that engaging in short-term aerobic exercise may have a positive acute effect on selective attention. Hernández et al. (2021) suggested that aerobic fitness is beneficial for selective attention and inhibition, particularly during childhood.

Based on these findings, further researched have also investigated the underlying mechanisms through which aerobic exercise impacts selective attention. Dodwell et al. (2021) investigated the effects of different intensities of aerobic exercise on attention control mechanisms using event-related potentials (ERPs). The study found that moderate-intensity aerobic exercise can eliminate interference effects in attention control mechanisms and elicit a potential related to distractors, moderate exercise levels are optimal for enhancing cognitive processing efficiency, particularly in attentional allocation. Biochemically, it is found that engaging in rhythmic long-rope jumping enhances cognitive performance, particularly attention, by activating the central norepinephrinergic system, Norepinephrine plays a role in regulating both the dorsal and ventral attention networks, influencing the reorienting and shifting of attention (Yamashita and Yamamoto, 2021).

Generally, our results partially corroborate past evidence, which have suggested that coordination exercises may have a significant impact on children's concentration and performance accuracy (Gallotta et al., 2015). Specifically, the positive influence we observed of the rope-skipping training on attention performance in children aged 7–9 years may be related to the activation of specific shared neural structures in cognitive and motor coordination, such as the cerebellum and prefrontal cortex (Henschke and Pakanm, 2023). Based on these assertions, this study's findings concur with past evidence suggesting that incorporating coordination exercises into the lives of children and adolescents can enhance their utilization of attentional resources and optimize the efficiency of their neural cognitive processing (Shi and Feng, 2022). Therefore, in the physical education of school-aged children, the use of tasks and exercises that stimulate cognitive engagement may provide effective pathways for enhancing cognitive function.

This study has several limitations. Firstly, the d2 analysis did not control for potential confounding factors such as age, educational background, and additional neuropsychological assessments, which could influence the results. Future studies should include these controls to enhance the robustness of the findings. Secondly, the use of a quasi-experimental design without randomization may have introduced potential biases and limited the ability to draw causal conclusions. Future research should aim to employ a randomized controlled trial design to minimize these biases and strengthen the validity of the results. Additionally, the study's reliance on psychometric assessments may have inherent limitations in accuracy and objectivity. Incorporating more objective measures, such as neuroimaging assessments, could provide a more comprehensive understanding of the effects of fancy rope-skipping on motor coordination and selective attention. Despite these limitations, the findings provide valuable insights into the potential benefits of fancy rope-skipping for children's cognitive and coordination development. Future research should continue to explore these relationships with more rigorous methodologies and larger sample sizes to confirm and extend these findings.

5 Conclusions

In conclusion, our study suggested that a 10-week fancy rope-skipping intervention may potentially enhance motor coordination and selective attention accuracy in children aged 7–9 years. The fancy rope-skipping intervention offers a simple, cost-effective, and engaging way to promote physical activity while simultaneously enhancing cognitive functions such as attention and coordination. Incorporating such interventions into school curricula or extracurricular activities could contribute to the holistic development of children, fostering not only physical fitness but also cognitive skills essential for academic success and overall wellbeing. Furthermore, our study underscores the importance of regular physical activity programs tailored to children's developmental needs. By integrating activities that target both motor coordination and selective attention, educators and practitioners can support the comprehensive development of children's physical and cognitive abilities.

Data availability statement

The data are available from the corresponding author on reasonable request.

Ethics statement

The studies involving humans were approved by Ethics Committee of Hainan Institute of Sports Science (GT-QM-03). 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

LD: Methodology, Writing – original draft. HW: Conceptualization, Writing – original draft, Writing – review & editing. HR: Supervision, Writing – review & editing. DX: Investigation, Writing – review & editing. SP: Formal analysis, Writing – review & editing. MS: Data curation, 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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Motor self-efficacy and physical education in school bullying

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In recent years, there has been a notable increase in bullying rates in school. Bullying is characterized as a repeated set of malicious actions by an individual or group toward another individual in an imbalanced power dynamic, resulting in physical, psychological, social, or material harm to the victim, with the intention of causing social exclusion. The scientific literature has investigated the factors that influence this type of behavior, environmental factors, such as school location and student age, as well as other factors, such as gender and level of physical fitness, also play an important role. This study examined the correlation between motor self-efficacy and bullying, considering that physical activity acts as a regulator in these cases. The Kolmogorov-Smirnov test was employed to assess the normality of the data distribution, and Spearman's Rho test was used to analyze the relationship between each dimension of the EBIPQ and E-AEM scores. The Cronbach's alpha was used to evaluate the reliability of each instrument. The results indicated a significant inverse correlation between the EBIP-Q and E-AEM in the variables of sex, educational stage and school environment. In conclusion, an inverse correlation was observed between motor self-efficacy and bullying, indicating that higher levels of motor self-efficacy are related to lower levels of bullying victimization. Motor self-efficacy could be used as a tool to reduce bullying situations at school. It would be important for government policies to encourage the practice of physical activity in all areas of life in order to improve motor self-efficacy and end bullying.

KEYWORDS

bullying, motor self-efficacy, adolescents, school, health

1 Introduction

Physical activity has become a tool for maintaining health because of the multiple benefits that it brings in different areas, such as psychological, physical, social, and physiological, increasing the quality of life of the person who practices it (Ai et al., 2021; Denche-Zamorano et al., 2022). International institutions, such as the World Health Organization (WHO), establish minimum recommendations for physical activity to maintain health according to the age and characteristics of the person; however, a high percentage of the world's population does not comply with these indications (World Health Organization, 2020, 2023). Specifically, in Spain, physical activity reports show that more than one-third of individuals aged between 15 and 69 years do not meet these recommendations (Ministerio de Sanidad, 2018). The rates of sedentary lifestyle and physical inactivity, in addition to entailing health problems, play a more important role in adolescents, as this is when physical changes occur and personality is built, establishing a critical period for the formation of habits and behaviors that can be maintained in the future In this sense, physical education is a means by which strategies can be developed to

encourage physical activity and promote healthy social habits, with the aim of providing them with tools to improve their health. Physical activity and exercise also play important roles in the regulation of student behavior. On the one hand, it has a social factor, in which students must interact with each other in class to achieve the established objectives, with interaction based on respect, teamwork, and empathy; on the other hand, it acts as an emotional regulator (Welk and Schaben, 2004; Greco, 2021). It also has a strong influence on self-concept, which refers to a person's self-perceived knowledge and beliefs about themselves, encompassing elements such as physical, emotional and social aspects. Physical self-concept, is of utmost importance in the adolescent stage.

Bullying is defined as the set of actions repeated over time with the malicious character of a person or group toward another individual in a power imbalance relationship, in which the victim suffers physical, psychological, social, or material damage, with the aim of achieving social exclusion. It can occur in different contexts and environments, although it is more frequent in schools, where students spend more than 6 h a day and become one of the places where students spend more time. Therefore, it is important to make this environment a safe space and eliminate this type of behavior (Roland, 2002; Hamburger et al., 2011). This type of bullying has very negative consequences for the health of the victims, since in addition to multiple behavioral disorders, they may experience anxiety, depression, or suicidal ideas, as well as isolation and avoidance of attending school (Jimenez-Barbero et al., 2020), and their academic performance suffers. Despite the efforts of the educational community to prevent the spread of this type of behavior, recent studies in Spain show that school bullying is still more common than cyberbullying (Pichel et al., 2021), and the rate of students who suffer bullying is 30%, or about a third of students (Llorent et al., 2021), representing an important social problem. For the characterization of abusive and victimizing behaviors of bullying, the European Bullying Intervention Project Questionnaire (EBIP-Q; Brighi et al., 2012) was developed and subsequently validated in Spanish (Ortega-Ruiz et al., 2016) for the quantification of these cases. Studies related to bullying and the relationship with the practice of physical activity found that this improves factors such as self-esteem and perceived self-efficacy, in addition to the transmission of prosocial values, fundamental elements in the prevention of conflictive behaviors such as bullying and victimization of this same event (Pelegrín Muñoz et al., 2010), so that physical exercise is a fundamental tool in the prevention of these conflictive attitudes.

Researchers have studied the variables and factors involved in students' violent and abusive behaviors, which can act as protective factors for victims and preventive factors to avoid their development, with the aim of improving students' experiences in high schools and making them safe environments for all. Among these factors, physical activity has been studied, and it has been found that those who do not meet the minimum recommendations are more likely to suffer bullying (García-Hermoso et al., 2020). The consequences of this have also been studied, such as motor self-efficacy, defined as the perceived ability of each individual about his or her motor skills with respect to the challenges and obstacles that appear in everyday life and his or her ability to overcome them successfully (Hernández-Álvarez et al., 2011a). It has been shown that this variable affects academic performance, and specifically in the field of physical activity, acts as an emotional and behavioral regulator, decreasing the incidence of undesirable behaviors in individuals as they have greater motor auto efficacy (Pajares and Valiante, 2002; Greco, 2021). Studies in this area show that this variable can have protective and preventive effects on abusers and victims (Jimenez-Barbero et al., 2020). The Motor Self-Efficacy Scale (E-AEM) tool (Hernández-Álvarez et al., 2011a), enables the quantification of the level of motor self-efficacy perceived by students and identifies profiles and risk situations in this regard. Habits are determined and conditioned by the environment and the situation of the individual, such as the location of the school and the educational stage of the student.

TABLE 1 Participants' sociodemographic traits ($N = 1,155$).

Variables	Categories	N	%
School type	Public	869	75.2
	Private	286	24.8
Educational stage	CSE	877	75.9
	Baccalaureate	278	24.1
Sex	Male	564	48.8
	Female	591	51.2
School environment	Rural	368	31.9
	Urban	787	68.1

N, number; %, percentage.

For a better understanding of the context of the article, the sample chosen is in secondary education, divided between compulsory secondary education and baccalaureate. In Spain, the educational system consists of primary education, with students from 6 to 12 years of age; compulsory secondary education (CSE), consisting of four academic years from 12 to 16 years of age with a compulsory character where physical education is compulsory; and baccalaureate, consisting of two non-compulsory courses, where physical education is compulsory in the first course but not in the second.

For this reason, the aim of this study was to examine the associations between the motor self-efficacy scale and the EBIP-Q questionnaire, exploring the possible protective effects for victims and preventive effects on the appearance of this type of behavior related to the perception of motor skills, as well as exploring the significant differences between sexes, location of the school, and educational stage, and to investigate whether environmental factors intervene in these two variables.

2 Materials and methods

2.1 Participants

The sample consisted of 1,155 secondary school pupils from South Spain's both public and private schools. A convenience sample method was used for recruitment. Table 1 presents the participant's sociodemographic data.

2.2 Instruments

First, a preliminary questionnaire was created that asked questions on the students' type of school, educational stage, sex, and school environment they attended in order to gather sociodemographic information about the participating sample.

Then, the Spanish version of the European Bullying Intervention Project Questionnaire (EBIPQ) was applied (Hernández-Álvarez et al., 2011a). It consists of 14 items encompassed in two main dimensions, seven of which describe victimization-related features (Dimension 1) and seven of which relate to aggressiveness (Dimension 2). The items are behaviors like hitting, insulting, threatening, stealing, swearing, excluding, or spreading rumors, and they apply to both dimensions. Each item is designed in the format of a Likert scale, with a score between 0 and 4, where 0 denotes "Never" and 4 denotes "Always," with a time span of the preceding 2 months. Finally, to gauge the level of motor self-efficacy in the school population, the Spanish version of the Motor Self-Efficacy Scale (E-AEM) was used (Hernández-Álvarez et al., 2011b). Ten questions on this test explain hypothetical situations that might occur when performing physical activity. A Likert-type scale is used, with values ranging from 1 to 4, with one signifying "totally disagree" and four signifying "totally agree." A score is produced by applying the scale, with a minimum value of 10 denoting a low level of motor self-efficacy and a maximum value of 40 denoting the highest level of self-efficacy perception. According to the authors, Cronbach's alpha reliability was 0.89. Moreover, in this research, the victimization and abuser dimensions Cronbach's alpha values were 0.854 and 0.856, respectively, so they are defined as satisfactory. Additionally, the E-AEM result (Cronbach's Alpha = 0.907) could be regarded as excellent.

2.3 Procedure

Access was gained to the Department of Education and Employment's database in order to determine which schools provide physical education courses for Secondary Education through Baccalaureate (from 12 to 18 years of age). Inquiries on the availability of scheduling a researcher visit so that they may administer the questionnaire to the students who had their parents' informed consent were made via email to the physical education teachers working at these schools. They were also invited to respond to the inquiries using the same channel. The study's objectives, the parents' informed consent, and the instrument models used were all described in the email. If the instructors were willing to collaborate, they had to respond to the email by scheduling a time for a researcher to visit the school and, after getting parental consent, interview the students about bullying. Initial access to the questionnaire was provided to the students via a tablet, and each item was explained to them one at a time so they wouldn't have any doubts when responding. In order to prepare the data for a second researcher's later, blind analysis, the researchers sorted, cleansed, and anonymized the data after every questionnaire had been gathered.

A protocol adhering to the guidelines of the Declaration of Helsinki was approved by the Biosafety and Bioethics Committee of the University of Extremadura in Spain (Registration Code 71/2022).

2.4 Statistical analysis

In the present study, SPSS statistical software version 23 for MAC (IBM SPSS, Chicago, IL, USA) was used to process the data collected. A Kolmogorov-Smirnov test was first performed to examine the assumption of normality in the distribution of the continuous variables, and it was found that this assumption was not met; therefore, non-parametric statistical tests were used. To analyze the possible differences in the dimensions of the EBIPQ and in the total score of the E-AEM according to educational stage, sex, and school environment, the Mann-Whitney *U*-test was used. Likewise, Spearman's rho test was used to examine the relationship between variables. The thresholds proposed by Mondragón Barrera (2014) were adopted to interpret the correlation coefficients, ranging from 0.01 to 0.10 (low correlation), 0.11 to 0.50 (medium correlation), 0.51 to 0.75 (considerable correlation), 0.76 to 0.90 (very high correlation), and 0.91 to 1.00 (perfect correlation).

Finally, the Cronbach's alpha was used to examine the reliability of each instrument. The criteria set out by Nunnally and Bernstein (1994) were used as a reference to interpret the reliability test values as follows: <0.70 (low), 0.71–0.90 (satisfactory), and >0.91 (excellent).

3 Results

The scores obtained in both dimensions of the EBIPQ in terms of the categories belonging to the variables analyzed are shown in Table 2. When observing the educational stage, both CSE and baccalaureate students showed similar scores for victimization behaviors; however, significant differences were found for perpetration, with baccalaureate students expressing higher values. Likewise, sex seemed to influence both dimensions of the EBIPQ, showing different results. On the one hand, females were more related to victimization habits while males, on the other hand, reported higher perpetration habits. Finally, the school environment did not show differences in victimization behaviors; however, students from urban environments were designated more aggressive.

The total scores extracted from the participants and their differences according to the categories explored are listed in Table 3. High school students reported higher motor self-efficacy in the context of PE than their CSE peers. Similarly, the male students expressed higher levels of motor self-efficacy. In contrast, the educational environment of the school did not appear to be a determinant.

We also explored the possible correlations between the dimensions of the EBIPQ and the final E-AEM scores (Table 4) by comparing these associations in various categories of interest. In general, the dimension related to victimization showed mean, inverse, and significant correlations; on the other hand, no significant associations were found in aggressive behaviors, either

TABLE 2 EBIPQ by educational level, sex, and school environment.

Item	Educational stage			Sex			School environment		
	CSE Me (IQR)	Baccalaureate Me (IQR)	*p*	Male Me (IQR)	Female Me (IQR)	*p*	Rural Me (IQR)	Urban Me (IQR)	*p*
1) Victimization	1.86 (0.9)	1.86 (0.9)	0.80	1.71 (0.8)	1.86 (0.7)	<0.01**	1.86 (0.9)	1.86 (0.9)	0.28
2) Perpetration	1.43 (0.6)	1.50 (0.7)	<0.01**	1.43 (0.7)	1.43 (0.6)	<0.01**	1.29 (0.6)	1.43 (0.7)	<0.01**

Me, median value; IQR, interquartile range.
Differences are significant at **p < 0.01. Each score is obtained is based on a Likert scale (0–4): 0 is "Never" and 4 "Always."

TABLE 3 Descriptive results of the E-AEM based on educational stage, sex, and school environment.

E-AEM	Educational stage			Sex			School environment		
	CSE Me (IQR)	Baccalaureate Me (IQR)	*p*	Male Me (IQR)	Female Me (IQR)	*p*	Rural Me (IQR)	Urban Me (IQR)	*p*
ΣE-AEM	31 (9)	32 (9)	<0.01**	33 (8)	29 (9)	<0.01**	32 (9)	31 (9)	0.32

Me, median value; IQR, interquartile range.
Differences are significant at **p < 0.01. Each score obtained is based on a Likert scale (1–4): 1 is "Totally disagree" and 4 "Totally agree."

at the general level or in any of the variables. For both CSE and baccalaureate students, the correlations in the first dimension were average, significant, and inverse, and were higher in the latter. As for sex, the victimization questions also showed mean, inverse, and significant associations, with male students expressing the highest coefficients. Finally, students from rural environments expressed greater relationships between motor self-efficacy and the victimization dimension than students from urban schools.

Finally, Table 5 shows the relationships between the scores obtained by the participants on both questionnaires. At the general level, bullying and motor self-efficacy were inversely correlated, low, and significant. When analyzing educational stage, only CSE students showed significant associations, which were inverse and medium. However, sex did not show significant correlations in any of the groups. Finally, self-efficacy and bullying were significantly related only in rural environments, and this association was characterized as medium and inverse.

4 Discussion

The main objective of this study was to explore the possible correlations between the EBIPQ and E-AEM scales, to determine whether the perceived motor efficacy of students could act as a protective or preventive factor of bullying, and to test the possible differences between sex, school location, and educational stage in which the students are in relation to these two tools.

First, we analyzed the significant differences that might exist between the three study variables related to EBIPQ scores: educational stage, sex, and school location. In the educational stage, those in the baccalaureate group had significantly higher scores than those in the CSE stage. In line with the results obtained in this work, the scientific literature supports these results, explaining that it may be due to the fact that older students publicly recognize that they are aggressors because of the social effect of recognizing power over others, feeling a kind of reward (Romera et al., 2016). Other studies also support these results by finding positive correlations between age and the perpetuation of bullying situations, establishing that older students tend to adopt this behavior to a greater extent than middle school students (Walters, 2021; Li et al., 2022). As a second variable, sex was analyzed in search of significant differences in the dimensions of the bullying questionnaire. The results show significant differences between sexes in both dimensions, with girls scoring higher in the victim dimension and boys scoring higher in the bully dimension. Although some studies find sex as a moderating variable in the effect on the aggressor dimension (Li et al., 2022), published studies do not find a consensus on which sex occupies each role the most. In articles that used the same tool, they found results similar to those of this study, in which boys had a higher prevalence in the aggressor area and girls in the victim area (González-Cabrera et al., 2020; Pichel et al., 2021). In contrast, other studies show that boys are more involved in both roles (Herrera-López et al., 2017; Feijóo et al., 2021; Obregon-Cuesta et al., 2022; Zhou et al., 2022). Finally, differences between rural and urban environments were studied, finding significant differences in the perpetration dimension, with those in urban schools scoring higher. In this sense, the scientific community also does not reach a consensus on the behavior of students depending on the environment in which the school is located, since some researchers find similar results to those found in this work (Cabrera et al., 2022) and other researchers find a higher degree of victimization in rural areas than in urban areas (Rodríguez-Álvarez et al., 2022), or even the opposite results to those found in this study, where students in rural environments are more involved in bullying than their counterparts in urban environments (Zhang et al., 2019). Owing to the scarcity of articles comparing these two variables, it is difficult to draw conclusions or explain this behavior. Further research is required in this regard.

In the statistical analyses of the E-AEM scale, significant differences were found with regard to educational stage, where high school students had a higher score, meaning that they had a higher motor self-perception than their CSE peers. In line with this finding, other authors agree with these results, stating that self-efficacy increases with age (Muñoz and García, 2013), although others report that the correlation is inverse, with those who were in earlier educational stages having higher self-efficacy

TABLE 4 Correlations between the EBIPQ and E-AEM scales by sex and educational level.

EBIPQ dimensions	ΣE-AEM ρ (p)	Educational stage		Sex		School environment	
		CSE Me (IQR)	Baccalaureate Me (IQR)	Male Me (IQR)	Female Me (IQR)	Rural Me (IQR)	Urban Me (IQR)
1) Victimization	−0.12 (<0.01)**	−0.12 (<0.01)**	−0.14 (<0.01)**	−0.11 (0.01)*	−0.10 (0.03)*	−0.15 (<0.01)**	−0.11 (<0.01)**
2) Perpetration	−0.01 (0.63)	−0.04 (0.23)	0.05 (0.37)	−0.01 (0.80)	−0.07 (0.09)	−0.06 (0.29)	0.01 (0.86)

Differences are significant at **p < 0.01; *p < 0.05.

TABLE 5 Correlations between E-AEM final score and EBIPQ score, according to educational stage, sex and school environment.

Item	EBIPQ ρ (p)	Educational stage		Sex		School environment	
		CSE Me (IQR)	Baccalaureate Me (IQR)	Male Me (IQR)	Female Me (IQR)	Rural Me (IQR)	Urban Me (IQR)
ΣE-AEM	−0.08 (<0.01)**	−0.11 (<0.01)**	−0.04 (0.54)	−0.07 (0.09)	−0.08 (0.06)	−0.12 (0.02)*	−0.06 (0.10)

Differences are significant at **p < 0.01; *p < 0.05.

due to the decrease in self-esteem in adolescence (Perea Chafé et al., 2016). Subsequently, statistically significant differences were found between sexes, with boys scoring higher than girls. This finding indicates that boys have a higher motor self-perception. The scientific literature finds similar results in this variable, explaining that motor self-efficacy is correlated with the practice of physical activity and enjoyment, finding that males generally perform more physical exercise than girls, so they have more development and motor self-perception (Çaglar, 2009; Hernández-Álvarez et al., 2011a; Chen et al., 2019; Ortiz Gómez, 2021).

Continuing with the results of the analysis of the correlations between the dimensions of the EBIPQ and the scores obtained in the E-AEM, we found significant inverse correlations in the victimization dimension, meaning that the higher the motor self-perception, the lower the score in the victim dimension, thus acting as a possible protective factor against bullying. This finding is in line with what has been found in other studies, which explain that high self-efficacy and motor skills are socially rewarded, and therefore, have social recognition and act as a protective agent (Kokkinos et al., 2015; Cao and Yang, 2018; Arcila-Arango et al., 2022). For the remaining variables, correlations of the same type were found in the victim dimension. In this sense, motor self-efficacy is a very important factor to consider in all contexts since it decreases the probability of bullying. The scientific literature finds physical activity and motor self-efficacy to be preventive tools for victims in all these contexts (Kokkinos et al., 2015; Cao and Yang, 2018; Benitez-Sillero et al., 2022). Taking the sum and global scores of both tools, the results show that the E-AEM has an inverse and significant correlation with the EBIPQ, demonstrating that high motor self-efficacy scores decrease bullying scores. Comparing the variables, significant correlations were only found in CSE, also with an inverse character, and in the rural environment, with correlations of the same nature. The scientific literature in this case provides an explanation for the correlation in CSE, where the score obtained in motor self-efficacy is higher because the levels of self-esteem are slightly higher and also act as an emotional regulator, in turn decreasing the occurrence of this type of conflictive behavior in the CSE stage, in addition to the fact that students perform more physical activity than students in higher grades (Waasdorp et al., 2019; Belcher et al., 2021).

4.1 Limitations and future lines

This study has certain limitations because it was conducted solely with students from the region of Extremadura, which means that the outcomes could be influenced by sociocultural factors. However, this presents an opportunity for further investigation in this field and opens up possibilities for future research. In addition, the data were gathered electronically, which has certain limitations (Nayak and Narayan, 2019). It would be worthwhile to investigate whether the results would have been the same if the questionnaires were delivered in a different format, if interviews were conducted, or if a qualitative study design had been utilized. In the future, it would be advantageous to expand the socio-demographic data of the participants to determine other variables that may clarify self-concept and self-esteem behaviors because one's perception of oneself could a risk factor for bullying, and to increase the sample size to include other communities at the national level.

4.2 Practical applications

The results obtained in this study are interesting. The fact that physical self-efficacy acts as a protective agent against bullying can be used as a tool to reduce the incidence of this phenomenon and improve school experience and coexistence. Physical activity is the means to improve physical self-efficacy, so physical education has the ideal means to promote prosocial values that improve this behavior, in addition to having the key to implementing pedagogical interventions in class to identify this type of behavior. Therefore, teachers have a scientific basis for optimizing this coexistence.

5 Conclusions

According to the study, physical self-efficacy is inversely related to bullying, so it can be used to reduce bullying situations at school to improve the coexistence of all students. Specifically, those who are in CSE and in rural areas have a higher risk of being a victim of bullying, so increasing physical self-efficacy, especially in these two contexts, would act as a protective agent against bullying, especially in the female sex. Therefore, it is important to apply these results in physical education in order to identify these situations and prevent them with the practice of physical activity.

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 and Biosafety Committee of the University of Extremadura (71/2022). 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

CG-A: Conceptualization, Data curation, Investigation, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. EF-F: Investigation, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. FC-R: Investigation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JR-R: Data curation, Methodology, Project administration, Resources, Software, Supervision, 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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Multilevel modeling of technology use, student engagement, and fitness outcomes in physical education classes

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Introduction: The integration of technology in educational settings, particularly in physical education, has shown potential in enhancing learning experiences and improving physical health outcomes. This study aims to investigate the effects of technology use on student engagement and fitness outcomes, considering the mediating role of student engagement and the moderating influence of personal attributes.

Methods: Utilizing a time-lagged design, the research collected data from 513 Chinese undergraduate students (52% male and, 48% female) aged between 18 and 24 years over three waves using structured questionnaires rated on a 5-point Likert scale.

Results: Results revealed a significant positive relationship between technology use and both student engagement (β = 0.68, p < 0.01) and fitness outcomes (β = 0.60, p < 0.01). Student engagement significantly mediated the relationship between technology use and fitness outcomes (β = 0.57, p < 0.01). Personal attributes moderated the effects of technology use on student engagement (β = 0.54, p < 0.01) and fitness outcomes (β = 0.52, p < 0.01), indicating varied benefits among students based on individual characteristics.

Discussion: These findings highlight the importance of tailoring technological applications in physical education to individual needs, suggesting that personalized approaches can significantly enhance the effectiveness of technology in improving fitness and engagement.

KEYWORDS

technology use, student engagement, personal attributes, fitness outcomes, physical education

Introduction

The importance of technology use in physical education has been increasingly recognized in recent years (Niu, 2023), as educators seek innovative ways to enhance student engagement and improve fitness outcomes (Tang, 2023). Technology use refers to the integration of digital tools such as fitness trackers, mobile applications, and interactive software specifically designed for physical education (Zhamardiy et al., 2020). These tools aim to facilitate student participation, provide real-time feedback, and enhance physical activities, making them more engaging and personalized for students (Ferguson et al., 2022). A growing body of research illuminates the transformative potential of technology in educational settings (Deng and Yu, 2023; Fitria, 2023; Timotheou et al., 2023; Wang et al., 2023; Wijayanto et al., 2023), particularly

within the realm of physical education (El-Tanahi et al., 2024; Wallace et al., 2023). For instance, Østerlie et al. (2023) have shown that incorporating digital tools like fitness trackers and interactive apps can significantly increase student participation by making activities more engaging and accessible. Furthermore, Arufe-Giráldez et al. (2023) highlights that technology not only facilitates a more interactive learning environment but also provides real-time feedback, enabling students to monitor their progress and adjust their efforts in physical activities. This evidence suggests that technology, when effectively integrated, can serve as a powerful catalyst for enhancing the educational experiences and physical health of students, making a compelling case for its broader adoption in physical education curricula.

While the integration of technology in physical education is often associated with enhancing learning environments and potentially increasing activity levels, there is a notable gap in direct empirical evidence linking technology use specifically to improved fitness outcomes in students. Current literature predominantly highlights the role of technology in facilitating interactive experiences and providing feedback mechanisms (Esteve-Mon et al., 2023), but its direct effect on the physical health improvements over time remains underexamined. This oversight in research highlights the need for a focused examination of how technology impacts actual fitness achievements. Understanding this relationship is essential for substantiating claims about the benefits of technology in physical education (Calderón et al., 2020) and for designing interventions that effectively utilize technology to boost physical fitness (Skarzhinskaya and Sarafanova, 2020), thereby fulfilling the broader educational objectives of health and wellness promotion in schools.

In addition, the study seeks to explore the underlying mediating mechanisms by examining student engagement, a critical component often proposed as a bridge between technology use and fitness outcomes. Student engagement in physical education is defined as the degree to which students are involved, motivated, and actively participating in physical activities within their educational programs (Leo et al., 2022). Student engagement refers to the degree to which students are motivated, involved, and actively participating in physical activities during their educational program (Leo et al., 2022). This concept includes behavioral, emotional, and cognitive components, reflecting how invested students are in the physical education process (Fredricks et al., 2004). While previous research has established that technology can enhance the learning environment and potentially increase activity levels (Calderón et al., 2020), there is a less explored area regarding how this engagement translates into actual fitness improvements. The research gap lies in understanding the mediating role of engagement: how it specifically acts to transform the enhanced interactions provided by technology into measurable fitness gains. This aspect of student engagement is crucial because it provides insight into the process by which technological tools can be leveraged to not only capture students' interest but also to effectively improve their physical health outcomes. Addressing this gap allows for a more comprehensive understanding of the pathways through which technology influences physical education, offering valuable information for the design of more effective educational tools and strategies.

Moreover, the study seeks to explore the boundary conditions by investigating the moderating influence of personal attributes on the relationship between technology use and fitness outcomes. Personal attributes, such as baseline fitness levels, motivational orientations, and individual attitudes towards physical education (Bishop and Durksen, 2020), can significantly influence how students respond to technological interventions in their classes. While existing research has highlighted the broad benefits of technology in educational settings (Alharthi, 2020), there is a notable lack of detailed understanding of how these effects might vary among individuals with different personal characteristics. This investigation into personal attributes as moderators is crucial because it could reveal that the effectiveness of technology in enhancing fitness outcomes is not uniform but instead depends on specific individual factors. By identifying these conditions, the study can provide more targeted insights and recommendations for customizing physical education programs to better meet the diverse needs of students, thereby optimizing the impact of technology on physical health improvements (Figure 1).

Literature review

Technology use and student engagement

The relationship between technology use and student engagement in physical education is hypothesized to be positively correlated. There is burgeoning evidence that modern students, often termed digital natives, are inherently stimulated by technology (Reddy and Bubonia, 2020; Wallace et al., 2023). When physical education classes incorporate elements such as fitness trackers, interactive apps, virtual reality, and online platforms (Zhamardiy et al., 2020), these tools can transform routine exercises into engaging, personalized experiences. This is further substantiated by Calabuig-Moreno et al. (2020) who argued that students who used fitness apps and trackers in physical education classes showed higher levels of participation and enthusiasm compared to those who did not. Similarly, Yu and Jee (2020) found that interactive technologies in physical education increased student engagement and improved overall physical fitness and health outcomes.

According to Yu (2023), technology facilitates various engaging features that cater to students' interests and needs. For instance, wearable fitness trackers provide real-time feedback, allowing students to monitor their progress and set personal goals, which can be highly motivating (Ferguson et al., 2022). In addition, interactive apps offer personalized workout plans tailored to individual fitness levels, making activities more relevant and achievable (Zhamardiy et al., 2020). Further, gamification makes physical activities fun and competitive, appealing to students' sense of play and competition (Ryan and Deci, 2000). These features are expected to boost engagement by making physical education classes more enjoyable and meaningful. In addition, self-determination theory (SDT) posits that engagement is driven by fulfilling autonomy, competence, and relatedness needs. Technology addresses these needs by providing control over learning (autonomy), immediate feedback (competence), and social interaction opportunities (relatedness) (Ryan and Deci, 2000). Empirical evidence supports that technology can foster a more intrinsically motivated and engaged student body.

Mediating role of student engagement

The link between student engagement and fitness outcomes in physical education is essential to understand, as it is believed that higher levels of engagement can significantly boost physical health. When students are deeply involved in physical activities, they are more likely to put forth consistent effort, leading to better fitness results

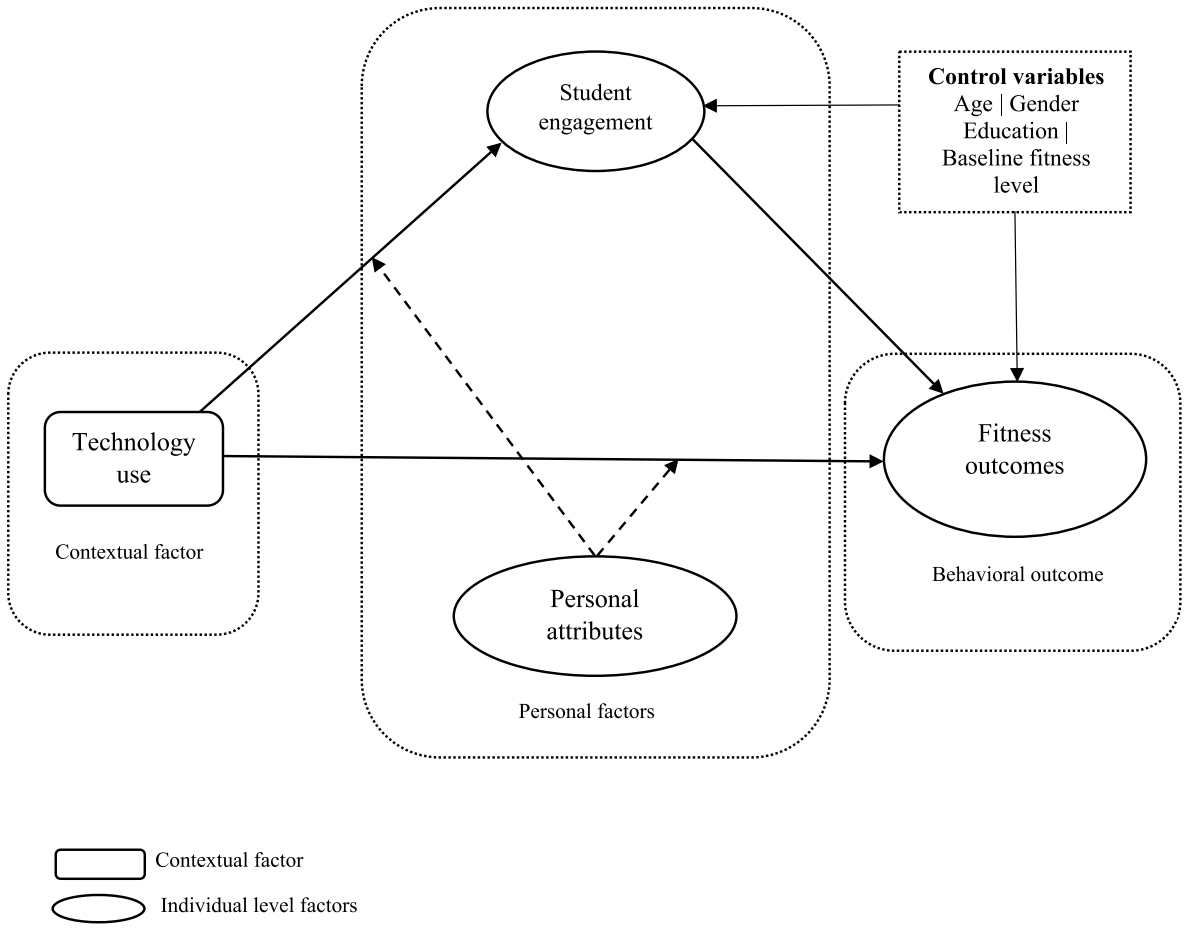

FIGURE 1
Proposed theoretical model.

(Nuss et al., 2021). Research by Fredricks et al. (2004) highlights that students who show higher levels of engagement not only perform better academically but also exhibit enhanced physical performance.

According to Noetel et al. (2023), engagement in physical education involves active participation, emotional investment, and cognitive focus on physical tasks. These dimensions collectively ensure that students are not only physically active but also mentally and emotionally committed to improving their fitness. Anchored on the self-determination theory (SDT), when students feel autonomous, competent, and connected to others in their physical education classes, their engagement levels increase, which in turn enhances their physical outcomes (Ryan and Deci, 2000). Empirical evidence supports this notion. For instance, De Bruijn et al. (2020) found a positive correlation between student engagement and the amount of physical activity students performed, which directly improved their fitness levels. This study demonstrates that engaged students tend to participate more vigorously and frequently in physical activities, thereby gaining better fitness benefits. Similarly, Goodyear et al. (2023) showed that students who were more engaged in their physical education classes experienced notable improvements in their cardiovascular health and overall physical condition. This focus on engagement is crucial because it emphasizes the importance of creating a supportive and motivating environment in physical education. When students are engaged, they are more likely to enjoy physical activities and adopt healthier lifestyles, which can have lasting impacts on their fitness and well-being. Hence,

Subsequently, the integration of technology in physical education can significantly enhance student engagement, providing interactive and motivating experiences that capture students' interest. This heightened engagement, driven by the use of digital tools such as fitness apps and wearable trackers (Goodyear et al., 2023), encourages more consistent and enthusiastic participation in physical activities. As students become more engaged through these technological interventions, they are likely to increase their physical activity levels (Leo et al., 2022), thereby improving their fitness outcomes. Thus, the use of technology not only makes physical education more engaging but also serves as a catalyst for better fitness achievements among students.

Moderating role of personal attributes

Moreover, the study anticipates that personal attributes serve as boundary conditions between technology use and student engagement, as well as the indirect relationship between technology use and fitness outcomes through student engagement. Personal attributes, such as baseline fitness levels, motivational orientation, and individual attitudes toward physical education (Schmidt et al., 2020), are likely to influence

how students interact with and benefit from technology in their physical education classes. For example, students with higher baseline fitness levels may be more inclined to use fitness trackers and apps effectively, resulting in greater engagement and subsequent fitness improvements. This notion aligns with findings from Pan (2020), who noted that individuals with a predisposition for physical activity tend to engage more with technological tools designed to enhance their workouts.

Motivational orientation is another critical personal attribute that can moderate the impact of technology on student engagement. According to Ryan and Deci (2000), students who are intrinsically motivated are more likely to engage deeply with educational content, including technology-enhanced physical education. When students find the use of technology enjoyable and aligned with their personal goals, their engagement levels are likely to increase (Lacka et al., 2021), leading to better fitness outcomes. This assumption is supported by the self-determination theory, which posits that autonomy, competence, and relatedness foster intrinsic motivation and engagement.

In addition, individual attitudes towards physical education also play a significant role in moderating these relationships. Students who have positive attitudes towards physical education are more likely to embrace technological tools and incorporate them into their fitness routines. As Alyoussef (2022) highlighted, students' perceptions of the usefulness and ease of use of technology significantly impact their willingness to engage with it. When students perceive technology as beneficial and easy to use, their engagement increases, subsequently improving their fitness outcomes.

Furthermore, personal attributes may influence the indirect relationship between technology use and fitness outcomes through student engagement. For instance, a student with a high level of intrinsic motivation might not only engage more with the technology but also sustain this engagement over time, leading to more significant fitness improvements. Conversely, a student with lower motivation might initially engage with the technology but fail to maintain this engagement, resulting in less pronounced fitness outcomes.

The moderating role of personal attributes suggests that technology's effectiveness in enhancing engagement and fitness outcomes is not uniform across all students. As Burton-Jones and Hubona (2005) noted, individual differences can significantly impact how students respond to educational interventions. By identifying and understanding these moderating factors, educators can tailor their approaches to better meet the diverse needs of their students, thereby maximizing the benefits of technology use in physical education.

Hypotheses

Based on the aforementioned justifications, the study puts forth the following hypotheses:

> *H1*: There is a positive relationship between technology use and student engagement.
>
> *H2*: There is a positive relationship between student engagement and fitness outcomes.
>
> *H3*: Student engagement mediates the relationship between technology use and fitness outcomes.
>
> *H4*: The direct relationship between technology use and student engagement is moderated by personal attributes, such as higher levels of personal attributes underpin this association.
>
> *H5*: The indirect relationship between technology use and fitness outcomes through student engagement is moderated by personal attributes, such as higher levels of personal attributes underpin this association.

Methodology

Sample and sampling

This study employed a quantitative methodology with a time-lagged design to investigate the impact of technology use in physical education classes on fitness outcomes, mediated by student engagement and moderated by personal attributes. The research unfolded across three waves spanning over 6 months, each strategically spaced to capture the evolving dynamics of the variables under consideration (Law et al., 2016).

The sampling strategy involved random selection to ensure a representative distribution of the population and to enhance the generalizability of the findings. A unique key was generated for each participant to match the responses across the three waves securely and accurately. This key was explained in a cover letter that accompanied each questionnaire, which also mentioned the study's adherence to ethical guidelines in line with the Declaration of Helsinki and relevant institutions. Further, informed consent was obtained from all participants, ensuring confidentiality, voluntary participation. The cover letter reassured participants of their anonymity and the secure handling of their data, addressing any potential concerns about privacy. The letter also reiterated the study's purpose, providing participants with a clear understanding of the importance of their consistent involvement across all three waves.

A total of 500 questionnaires were initially distributed to physical education students enrolled in Chinese universities in the first wave, which focused on collecting data on technology use, personal attributes, and demographic information. Of these, 543 responses were received due to the high participation rate; however, 30 responses were discarded due to incomplete or inconsistent answers, resulting in 513 valid questionnaires for the first phase.

In the second wave, aimed at measuring student engagement, 413 of the initial respondents were re-contacted, and 398 responses were successfully collected. The slight drop in participation was anticipated due to the longitudinal nature of the study.

The third and final wave targeted the measurement of fitness outcomes. All 398 participants from the second wave were invited to continue their participation, and 385 responded. After a detailed examination of these responses, 374 were deemed suitable for final analysis after consolidating the data and ensuring all entries met the study's stringent quality criteria.

The methodological framework and data collection phases were designed to minimize biases and maximize the reliability and validity of the findings. The time-lagged design allowed for an effective examination of the causal relationships between the variables, providing robust insights into how technology use influences fitness

outcomes through mechanisms of engagement, shaped by personal attributes.

Demographic

The demographic profiles of the participants are as follows: the gender distribution was nearly balanced, with 52% of the participants identifying as male and 48% as female. Age was uniformly distributed across the educational years, reflecting participation from all academic levels: 18% were first-year students, 27% were second-year students, 28% were third-year students, and 27% were fourth-year students, ensuring a representation from each stage of undergraduate education. Concerning education, 21% of participants were first-year students, 24% were second-year students, 33% were third-year students, and 22% were fourth-year students. Lastly, baseline fitness level was categorized into three levels to gauge initial physical fitness: 33% of the participants reported a low fitness level, 34% reported a medium fitness level, and 33% reported a high fitness level.

Control variables

In this study, several control variables were included to account for individual differences that might influence the relationships between technology use, student engagement, and fitness outcomes. The control variables—age, gender, education level, and baseline fitness level—were selected based on their potential impact on student responses to physical education interventions. Age was controlled for because physical fitness and engagement levels may vary with the developmental stage, as older students may demonstrate different physical readiness and motivation compared to younger students. Gender was also included to account for potential differences in how males and females engage with physical education and technology, as existing research suggests that males and females may have distinct preferences for fitness-related technology. Education level, or year of study, was controlled because students at different academic stages may have varying levels of engagement with physical education, influenced by their academic experiences and priorities. Baseline fitness level was particularly important, as students who begin with higher fitness levels may engage more actively and effectively with technology-enhanced physical education activities. Baseline fitness can affect a student's motivation and capacity to respond to physical education interventions, making it a critical factor to control when examining fitness outcomes. By accounting for these variables, the study aimed to isolate the effects of technology use and student engagement on fitness outcomes and ensure that the results were not confounded by these individual characteristics.

Measures

The research instruments for this study were designed to gather precise and reliable data from participants. Structured questionnaires were utilized as the primary data collection tool, featuring items designed to gauge perceptions and behaviors across several dimensions related to technology use, student engagement, fitness outcomes, and personal attributes in physical education settings. To ensure a standardized approach to responses, each item in the questionnaires was formatted using a 5-point Likert scale, ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree").

The technology use scale was adapted from existing validated instruments found in the work Kahveci (2010) and included five specific items. A sample item from this scale is, "I frequently use digital tools and apps in my physical education classes." Similarly, the items measuring student engagement were developed by drawing insights from the foundational research by Fredricks et al. (2004), ensuring that the constructs were contextually relevant and grounded in educational psychology. The fitness outcomes scale included measures such as "My endurance has improved since the start of the semester," reflecting physical development attributes typically impacted by engaged participation in physical education, adapted from Caspersen et al. (1985). Lastly, the personal attributes items were influenced by the work of Reeve (2013), and included elements such as motivation and discipline, crucial for understanding individual differences in physical education engagement and outcomes.

Results

To examine the presence of common method variance (CMV), Harman's single factor technique was employed. The observed variables were evaluated by exploratory factor analysis, employing an unrotated solution and constraining the number of factors to one for the purpose of examining single factor assessment. The finding reveals that the maximum variance explained by single factor was 30.342% of the total variance, falling below the threshold of 50%, suggesting that the dataset did not exhibit any concerns related to common method variance (CMV) (Podsakoff et al., 2003). While this is a commonly used method, it has limitations, particularly in its sensitivity to detect more subtle forms of method bias. As such, relying solely on Harman's single-factor test may not provide a comprehensive assessment of CMV. To further strengthen the credibility of the results, future research could consider additional techniques for assessing CMV, such as the marker variable technique.

The study conducted confirmatory factor analyses (CFAs) using Mplus 7.4 to evaluate the discriminability of four key constructs: technology use, student engagement, fitness outcomes, and personal attributes. The analysis revealed that the proposed four-factor model demonstrated a good fit with the collected data, with a Chi-Square (χ^2) value of 339.03 and 271 degrees of freedom, suggesting the model's adequacy in representing the observed data. The Comparative Fit Index (CFI) and the Tucker-Lewis Index (TLI) both stood at 0.97, indicating a high degree of fit relative to the independent model. The Root Mean Square Error of Approximation (RMSEA) was 0.05 and the Standardized Root Mean Square Residual (SRMR) also at 0.05, both of which further support the model's goodness of fit.

In comparison, alternative models demonstrated poorer fit indices: a three-factor model combining Technology Use and Student Engagement resulted in a χ^2 of 755.24, CFI of 0.92, TLI of 0.92, RMSEA of 0.07, and SRMR of 0.09; a two-factor model that merged technology use, student engagement, and personal attributes showed a χ^2 of 3230.97, CFI of 0.68, TLI of 0.65, RMSEA of 0.17, and SRMR of 0.21; and a one-factor model combining all four constructs had a χ^2 of 6402.00, CFI of 0.31, TLI of 0.33, RMSEA of 0.27, and SRMR of 0.29. These comparisons underscore the superior performance of the

four-factor model over the alternatives, affirming the distinctiveness of the constructs within the study.

Table 1 presents the descriptive statistics and correlations for the constructs of technology use, student engagement, fitness outcomes, and personal attributes measured at different times. The Cronbach's alpha values, indicating internal consistency, are exceptionally high for all constructs, ranging from 0.90 to 0.97, which suggests that the scales used to measure these constructs are reliable.

Technology use (T1) has a mean of 4.07 and a standard deviation of 0.50. It shows significant negative correlations with student engagement (T2) and personal attributes (T1), with coefficients of −0.49 and −0.29 respectively, indicating that higher technology use may be associated with lower student engagement and less favorable personal attributes. It also negatively correlates with fitness outcomes (T3) but to a lesser extent, with a coefficient of −0.20.

Student engagement (T2) is recorded with a mean of 3.91 and a standard deviation of 0.89. It positively correlates with fitness outcomes (T3) and personal attributes (T1), with coefficients of 0.62 and 0.22, suggesting that higher engagement is linked with better fitness outcomes and more favorable personal attributes.

Fitness outcomes (T3) has a mean of 3.83 and a standard deviation of 0.85, showing positive correlations with both student engagement (T2) and personal attributes (T1) with coefficients of 0.20 and 0.21, respectively. This indicates that improvements in fitness outcomes are moderately associated with higher engagement and more favorable personal attributes.

Personal attributes (T1) has a mean of 3.87 and a standard deviation of 0.83, and it shows a positive correlation with fitness outcomes (T3) and a negative correlation with technology use (T1), suggesting that favorable personal attributes might support better fitness outcomes while potentially being compromised by higher technology use.

Overall, the table reflects a complex interaction between technology use, student engagement, personal attributes, and fitness outcomes, highlighting the intricate dynamics within physical education settings.

The analysis of control variables provided additional insights into how individual differences affected student engagement and fitness outcomes. Age did not significantly influence either student engagement or fitness outcomes, indicating that the effects of technology use were consistent across different age groups. However, gender had a significant impact on fitness outcomes, with male students reporting slightly higher improvements in their fitness levels compared to females, although gender did not significantly affect student engagement. Education level showed a small but notable effect on student engagement, with students further along in their studies displaying higher engagement in physical education activities. This suggests that older students may have more developed skills or motivation to engage in physical education. In contrast, baseline fitness level was a strong predictor of fitness outcomes, as students who started with higher levels of fitness experienced greater improvements. However, baseline fitness had no significant effect on student engagement, suggesting that students across fitness levels were similarly engaged with the technology-enhanced activities.

In addition, Table 2 outlines the results of hypothesis testing for the study, examining the effects of various factors on student engagement and fitness outcomes at both individual and group levels.

TABLE 1 Correlations and descriptive statistics.

Construct	Mean	SD	1	2	3	4
1. Technology use (T1)	4.07	0.50	(0.90)	−0.49**	−0.20**	−0.60*
2. Student engagement (T2)	3.91	0.89	−0.23**	(0.94)	0.62**	0.54**
3. Fitness outcomes (T3)	3.83	0.85	−0.10*	0.20**	(0.97)	0.43**
4. Personal attributes (T1)	3.87	0.83	−0.29**	0.22**	0.21**	(0.96)

Values in diagonal report Cronbach alphas; values below and above diagonal reflect individual and contextual level correlations; T1, Time 1; T2, Time 2; T3, Time 3, $^{**}p < 0.01$, $^{*}p < 0.05$.

TABLE 2 Hypothesis testing.

	Student engagement				Fitness outcomes			
	B	se	*p*	95% CI	*B*	se	*p*	95% CI
Within level								
Age	−0.04	0.03	0.79	[−0.15, 0.14]	0.02	0.02	0.70	[−0.05, 0.06]
Gender	−0.02	0.05	0.58	[−0.17, 0.12]	0.18**	0.07	0.01	[−0.32, −0.03]
Education	0.06*	0.05	0.02	[0.01, 0.13]	0.02	0.03	0.30	[−0.05, 0.08]
Baseline fitness level	0.03	0.03	0.21	[−0.02, 0.11]	0.03	0.02	0.48	[−0.04, 0.07]
Student engagement					0.07	0.04	0.15	[−0.03, 0.20]
Between level								
Technology use	0.68**	0.12	0.00	[0.39, 0.93]	0.60**	0.15	0.00	[0.30, 0.90]
Student engagement					0.60**	0.12	0.00	[0.31, 0.90]
Personal attributes	0.54**	0.03	0.00	[0.38, 0.70]	0.52**	0.11	0.00	[0.34, 0.69]
Technology use × personal attributes	0.57**	0.12	0.00	[0.38, 0.74]	0.63**	0.15	0.00	[0.48, 0.83]

$^{**}p < 0.01$, $^{*}p < 0.05$.

At the individual level, age showed no significant impact on student engagement or fitness outcomes, with beta coefficients near zero and high *p*-values, indicating a lack of strong influence. Gender also did not significantly affect student engagement, but it did positively impact fitness outcomes, suggesting that gender might play a role in how fitness is affected in the educational context. Education level had a small but significant positive effect on student engagement, suggesting that higher educational levels might boost engagement in physical activities. Baseline fitness level and student engagement, when tested as predictors, showed no significant influence on the fitness outcomes, although the directions of their effects were positive.

The results from Table 2 strongly support the hypothesis that technology use significantly enhances both student engagement and fitness outcomes in physical education classes. The positive impact of technology use is reflected in the substantial beta values for student engagement ($\beta = 0.68$, $p < 0.01$) and fitness outcomes ($\beta = 0.60$, $p < 0.01$), indicating that technology integration is crucial for improving these aspects of physical education.

Personal attributes also play a significant role in influencing both student engagement and fitness outcomes, as evidenced by positive beta values ($\beta = 0.54$ for engagement and $\beta = 0.52$ for fitness outcomes, both with $p < 0.01$). This finding suggests that individual characteristics can significantly contribute to how students engage and benefit from physical education programs.

Furthermore, the interaction between technology use and personal attributes shows even stronger effects, with beta values of $\beta = 0.57$ for engagement and $\beta = 0.63$ for fitness outcomes (both $p < 0.01$). This interaction indicates that the benefits of technology use are enhanced when aligned with favorable personal attributes, leading to even greater improvements in engagement and fitness outcomes. The result of this analysis is also shown in the form of simple slope analysis in Figure 2.

Overall, these results highlight the critical importance of considering both technology use and personal attributes in designing effective physical education programs that can significantly enhance student engagement and fitness outcomes. The findings support the integration of tailored technological solutions that complement individual student characteristics to maximize educational and health benefits in physical education settings.

Discussion

The study set out to explore the relationship between technology use in physical education and its impact on student engagement and fitness outcomes, while examining the mediating role of student engagement and the moderating effects of personal attributes. We successfully met these objectives, offering a nuanced understanding of how technology influences physical education.

First and foremost, technology use and fitness outcomes demonstrated a significant positive relationship, indicating that the incorporation of technology in physical education leads to improved physical health metrics among students. This aligns with findings from prior research such as Lai and Bower (2019) and (Yu, 2023), which suggest that technological tools can enhance the learning environment by providing interactive and engaging ways to participate in physical activities. These tools not only facilitate a more dynamic interaction with physical education content but also provide immediate feedback that can motivate students to push their physical limits (Lai and Bower, 2020).

Second, the role of student engagement as a mediator adds depth to our understanding. It suggests that technology's impact on fitness outcomes is partially driven by how it increases student engagement. This is in line with theories like the Self-Determination Theory (Ryan and Deci, 2000), which emphasize the importance of engaging educational environments in enhancing intrinsic motivation, thereby improving learning and performance outcomes. In our study, the data indicated that higher levels of engagement, fostered by technology use, directly correlate with better fitness results, supporting the argument that engaged students are more likely to benefit physically from their educational experiences.

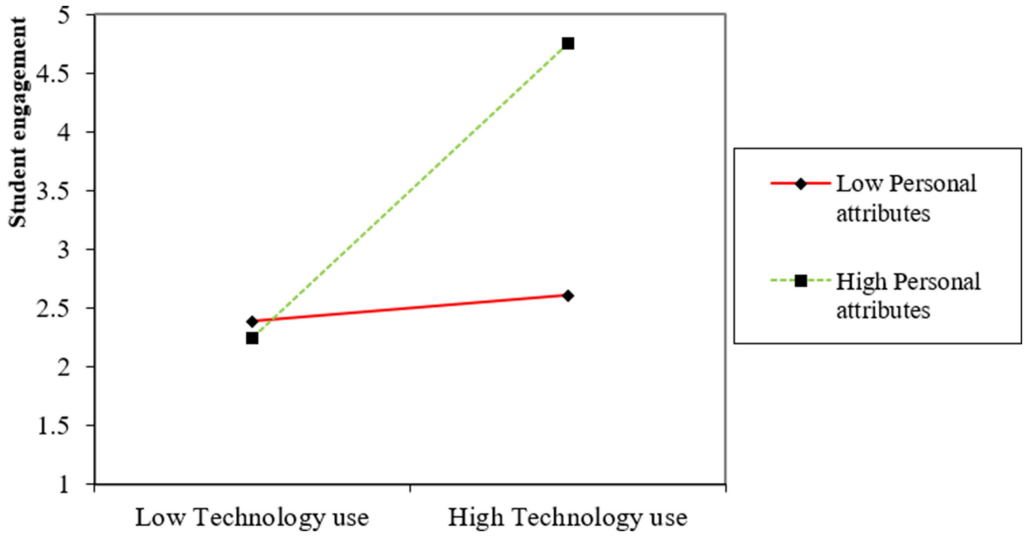

FIGURE 2
Moderation effect of personal attributes.

Moreover, the moderating role of personal attributes revealed that the benefits of technology in physical education are not uniformly experienced by all students. Instead, these benefits are more pronounced in students with specific characteristics such as higher baseline fitness levels or more positive attitudes towards physical education. This insight is crucial as it suggests that while technology can be a powerful tool, its effectiveness is contingent on individual differences (Chocarro et al., 2023). This finding encourages further investigation into personalized educational approaches that could maximize the effectiveness of technology-based interventions.

The moderated mediation analysis further demonstrated that the relationship between technology use and fitness outcomes through student engagement is significantly influenced by personal attributes. This complexity highlights the importance of considering individual student profiles when designing and implementing technology in physical education programs, ensuring that these interventions are tailored to meet diverse student needs and optimize educational outcomes.

In summary, the study contributes to the broader discourse on educational technology by demonstrating that while technology can significantly enhance physical education outcomes, the extent of its effectiveness depends substantially on how it interacts with student engagement and individual differences. This calls for a more personalized approach in the deployment of technology in educational settings, aiming to cater to the varied needs of students to fully harness the potential of technological advancements in education.

Theoretical implications

The theoretical implications of this study are profound, contributing significantly to our understanding of the dynamics between technology use in educational settings, particularly in physical education, and its effects on student outcomes. These findings enrich the theoretical landscape in several key ways.

Firstly, the positive relationship between technology use and both student engagement and fitness outcomes support and extends existing educational theories that advocate for the integration of technology to enhance learning experiences. The findings affirm theories like the Technology Acceptance Model (TAM, Natasia et al., 2022), which posits that perceived usefulness and ease of use influence individuals' acceptance and use of technology. By demonstrating that technology use in physical education can lead to improved fitness outcomes, this study provides empirical support for TAM in the context of physical education, suggesting that the benefits of technology are not only perceived but are also manifested in tangible improvements in student fitness levels.

Moreover, the mediation effect of student engagement between technology use and fitness outcomes offers a theoretical extension to the Self-Determination Theory (SDT, Ryan and Deci, 2000). According to SDT (Ryan and Deci, 2000), supportive environments that fulfill students' needs for autonomy, competence, and relatedness can enhance motivation and engagement. The findings from this study suggest that technology acts as a catalyst in this environment, enhancing engagement by providing students with innovative and interactive ways to participate in physical activities, which in turn improves their physical health. This reinforces the importance of engagement as a central mechanism through which technology influences educational outcomes, emphasizing the need for educators to focus on how technology can foster an engaging learning environment.

Additionally, the moderation of these effects by personal attributes introduces a nuanced perspective to the discussion, aligning with the Differentiated Instruction (DI) theory (Griful-Freixenet et al., 2020) which advocates for educational practices that are responsive to individual learner differences. The moderating role of personal attributes, particularly baseline fitness levels and motivational orientation, provides key insights into how students interact with technology in physical education. Students with higher baseline fitness levels may find technology-enhanced activities more engaging because they are already physically prepared to participate more actively. Their prior experience with physical activity could make them more confident and comfortable using fitness apps and trackers, leading to greater engagement and improved fitness outcomes. On the other hand, students with lower baseline fitness levels may encounter more challenges when engaging with physical tasks, which could lower their overall engagement. However, personalized workout plans and real-time feedback provided by technology could still offer benefits to these students, as they can track their progress and work toward achievable goals. This suggests that tailored interventions might be necessary to maximize the engagement and fitness outcomes for students with lower fitness levels.

Motivational orientation also plays an important role in moderating these relationships. Students with a higher level of intrinsic motivation are likely to engage more deeply with technology-enhanced physical education, as it aligns with their personal goals for self-improvement and health. The autonomy and real-time feedback provided by the technology meet their intrinsic needs for competence and achievement, further enhancing their engagement and fitness outcomes. In contrast, students with lower motivation may require more external encouragement or simplified technological features to stay engaged. These findings emphasize the need for educators to personalize technology-based interventions in physical education, taking into account the unique characteristics of each student, such as their baseline fitness levels and motivational orientation. By doing so, educators can optimize the benefits of technology and create more effective learning experiences for all students.

Practical implications

The practical implications of this study are significant for educators, policymakers, and curriculum designers, particularly in physical education. The findings provide actionable insights into how technology can be strategically utilized to enhance student engagement and improve fitness outcomes, informing several practical applications in educational settings.

The positive impact of technology use on student engagement and fitness outcomes suggests that schools and educational institutions should increase the integration of digital tools, such as fitness trackers, interactive apps, and virtual reality systems. These tools can make physical activities more engaging and measurable. Educators should be trained not only in the technical use of these tools but also in

pedagogical strategies that leverage technology to enhance student motivation and participation.

Given the moderating role of personal attributes, it is essential for physical education programs to adopt personalized approaches. Assessing students' baseline fitness levels, motivational orientations, and other personal characteristics at the beginning of courses can allow educators to tailor the use of technology accordingly. For example, students with lower fitness levels could benefit from technology-enhanced activities designed to gradually build their confidence and fitness.

These findings can also inform curriculum development, ensuring that technology is integrated in ways that align with educational goals. Curriculum designers should focus on structured lesson plans that incorporate technology for both instruction and feedback, providing students with a clear understanding of their progress and areas for improvement. Furthermore, the development of tailored interventions that consider individual student differences can further enhance engagement and outcomes.

In addition, the study suggests incorporating the taxonomy of teacher motivational behaviors (TMBs, Ahmadi et al., 2023). Using this classification of 57 behaviors related to autonomy, competence, and relatedness, educators can better support student motivation. For instance, offering choice in physical activities, providing individualized feedback, and fostering a supportive environment can enhance engagement and fitness outcomes.

At the policy level, the findings support the need for funding and resource allocation to expand technology integration in physical education. Policymakers can use this data to justify budget increases or to pilot programs that explore new forms of technology-enhanced physical education.

Lastly, schools should implement long-term monitoring and assessment strategies to evaluate the ongoing impact of technology on student engagement and fitness outcomes. This could include periodic surveys, fitness assessments, and feedback sessions, which would allow schools to continuously refine their approaches and maximize the benefits of technology in education.

By implementing these practical implications, educational institutions can significantly enhance the effectiveness of their physical education programs, leading to more engaged students and improved health outcomes.

Limitations and directions for future research

While this study provides valuable insights into the use of technology in physical education, it also comes with certain limitations that warrant further reflection. First, the sample was limited to Chinese undergraduate students, which restricts the generalizability of the findings to other cultural or age demographics. Physical education practices, technology adoption, and engagement with fitness tools may vary significantly across different cultural contexts, making it important to replicate this research with more diverse populations in future studies. Furthermore, the age group of undergraduate students might limit the applicability of the findings to other educational levels, such as high school students or adult learners.

A second important limitation lies in the reliance on self-reported measures for technology use, student engagement, and fitness outcomes. Self-reported data may introduce biases, such as social desirability bias, where participants might overstate their engagement or fitness improvements. This method of data collection may also be prone to inaccuracies due to the subjective nature of self-assessment. Future studies could enhance data accuracy by incorporating more objective measures of fitness, such as standardized fitness tests or wearable fitness trackers, which could offer more reliable insights into the actual physical improvements achieved.

Additionally, the relatively short time frame of this study limits the ability to make conclusive statements about the long-term effects of technology use on fitness and engagement. The time-lagged design allowed for observation of short-term changes, but a longer-term longitudinal study would provide more robust evidence of how technology influences physical fitness and student engagement over time. A study with multiple follow-up points could also better assess the sustainability of the benefits associated with technology use in physical education.

The study also did not differentiate between various types of technology, which may have different impacts on student engagement and fitness outcomes. Different digital tools, such as fitness trackers, virtual reality systems, or mobile applications, may influence student engagement and outcomes in unique ways. Future research could explore the comparative effects of different types of technology to better understand which tools are most effective in enhancing student engagement and fitness in physical education settings.

Finally, while personal attributes were considered as moderating factors, other important variables, such as socio-economic status, technological literacy, or institutional support for technology use, were not included in the analysis. These factors could significantly impact the effectiveness of technology-enhanced physical education, and their inclusion in future studies could provide deeper insights into the conditions under which technology enhances educational outcomes.

Future research should address these limitations by expanding the study to include more diverse populations from different regions and educational levels, incorporating objective measures of fitness and engagement, extending the study's duration, and exploring a wider range of moderating variables. These efforts would not only improve the theoretical frameworks underpinning this field but also refine the practical applications, leading to more personalized and effective educational strategies.

Conclusion

The study highlights the significant positive impact of technology use on student engagement and fitness outcomes in physical education, emphasizing the potential of digital tools to enhance learning experiences and promote physical well-being. The findings reveal that technology's effectiveness is mediated by student engagement and moderated by individual attributes, suggesting that personalized approaches in educational technology could maximize its benefits. While the study provides a solid foundation for integrating technology in physical education, future research should aim to

address its limitations by expanding the participant base, refining measurement methods, and exploring long-term effects. By continuing to explore these areas, educators and policymakers can better harness the transformative potential of technology to enrich physical education programs across diverse educational settings.

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 Department of Physical Education, Liaoning Normal 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: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. YS: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. XD: Writing – review & editing, Writing – original draft, Validation, Investigation, Funding acquisition, Conceptualization.

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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.2024.1458899/full#supplementary-material

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Can leisure education effect on screen time and perceived leisure benefits for college students?

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Background: Since children and adolescents usually spend their theoretical course time at schools, they experience many negative effects of inactivity and physical inactivity. They are disadvantaged in terms of facing many health and social problems due to lack of physical activity. This sedentary life increases their exposure to screens and the time they spend sitting.

Aim of the study: The first aim of this research is to conduct an experimental study to reduce the excessive screen time of college students with an exercise intervention. The second aim of the study is to examine the perceived benefits of leisure activities of students with an exercise intervention.

Methods: In this direction, the study group of the research, which was conducted as an experimental study, consisted of 176 [74 female (42.0%), 102 male (58.0%)] students studying in the department of mathematics at college. In the study, the screen exposure time of students was measured with the "Screen time scale for youth and adolescents" along with a personal information form. In addition, the "Perceived Leisure Benefit Scale" scale was used to evaluate the participants' awareness of the benefits obtained from leisure activities.

Results and conclusion: According to the findings of the research, it was determined that there was a positive and significant decrease in the screen time of the experimental group participants of students who participated in the research before and after the exercise intervention. In the Leisure Benefit Scale, it was observed that there were significant positive differences in favor of the experimental group.

KEYWORDS

physical education, leisure activities, screen time, college students, exercise and screen time

1 Introduction

The increased use of technology and screens in our daily lives has raised concerns about the negative effects it may have on our physical and mental well-being. In today's digital age, screen time has become a pervasive aspect of daily life for individuals of all ages. Whether it is for work, leisure, or education, screens have become an integral part of our lives.

Research has shown that excessive screen time, which includes activities such as watching television, playing video games, and using computers and digital devices, can have negative effects on cognition and mental health, particularly for children, adolescents, and young adults (Neophytou et al., 2021). Numerous studies have highlighted the detrimental effects of excessive screen time on cognitive development, including learning and memory (Mineshita et al., 2021; Lissak, 2018; Domingues-Montanari, 2017; Stiglic and Viner, 2019; Radesky and Christakis, 2016; Eric, 2021; Twenge and Campbell, 2018; Li et al., 2020; Muppalla et al., 2023; Must and Tybor, 2005; Hawi and Samaha, 2016; Rahimah, 2021). In response to these concerns, there has been a growing interest in implementing exercise interventions to counteract the negative effects of excessive screen time, especially among students. Physical activity has been widely recognized for its positive impact on cognitive functions, including attention, memory, and information processing (Donnelly et al., 2016; Bidzan-Bluma and Lipowska, 2018; Erickson et al., 2019).

When discussing the physical, psychological, sociological and economic benefits of leisure, the concept of an "improved condition" comes to the fore. One of the important ways to do this is to evaluate physical activities (running, cycling, swimming, etc.; Driver et al., 1991). Leisure Benefits are evaluated as the subjective perception of individuals after they participate in various activities in their free time to improve their personal conditions and meet their individual demands (Li et al., 2021). Therefore, these perceptions may differ among individuals. In previous studies, leisure benefits have been evaluated with various aspects such as physical, physiological, social, educational, esthetic and relaxation (Akgül et al., 2018). Ho (2008) used the Leisure Benefits Scale (LBS) as a reference to measure the leisure benefits of subjects in terms of physical, psychological and social aspects. The Physical Aspect measures the physical benefits (such as disease prevention and control) that an individual derives from participation in leisure and sports activities; the psychological aspect measures the individual's psychological benefits (such as personal growth and reduction of mental stress), and the social aspect measures the individual's social benefits (such as the development of social relationships and family ties).

By incorporating regular exercise into the daily routine of students in the mathematics department, it is possible to mitigate the potential social, health and cognitive challenges associated with excessive screen time.

In Turkey, mathematics students are at a disadvantage in terms of the opportunity to exercise regularly due to the sporting competencies of their faculties. Since there are no sports instructors in their departments, they need external support. The most dangerous thing for this group who are far away from sports and exercise is to start and quit sports. Because they may think that sports are not suitable for them and that they cannot have fun. For this reason, the exercise intervention implemented in this study was planned to be fun, not competitive. The leisure activities can be preferred because of the predominance of the fun aspect when starting sports. Students are directed to have fun and move enough, not to be compared in terms of success. The aim of this orientation is to increase the students' belief in the benefits they will gain from leisure activities when the intervention program is over. Thus, the possibility of students to include leisure sports as an exercise in their individual lives can be increased (Brown and Smith, 2018; Smith, 2019; Zaytsev et al., 2013). The exercise intervention determined in this respect was applied to the students as a regular leisure education. For 3 days a week, volleyball, basketball and futsal leisure activities were added to the weekly programs of the students with 2-h lessons. With this planning, it was aimed to overcome the lack of physical activity in students' daily lives to a certain extent. When we look at the university youth, it is seen that screen time increases not only in their social lives but also in their academic lives. Nowadays, one of the important areas where technology, in other words screens, are used is mathematics education. Computer and mobile technology have been incorporated into math classrooms to enhance learning experiences and improve student outcomes. However, the excessive use of screens and digital devices, including smartphones, tablets, and computers, has raised concerns about its potential negative impact on students' health and academic performance (Lissak, 2018; Sanz-Martín et al., 2022; Oswald et al., 2020; Adelantado-Renau et al., 2019; Hale and Guan, 2015; Twenge et al., 2018; Lauricella et al., 2015; Schmidt et al., 2020; Twenge et al., 2018; Tandon et al., 2012; Madigan et al., 2019; Maras et al., 2015; Lanningham-Foster et al., 2006; Davies et al., 2012). The increase in screen time not only for children and young students, but also for adults and especially the elderly negatively affects their quality of life (Davies et al., 2012; Nguyen et al., 2020; Schoeppe et al., 2016; Barr-Anderson et al., 2021; Guo et al., 2021; Colley and Saunders, 2023; Zhang et al., 2021; Ren et al., 2023; Lopes et al., 2023; Hsueh et al., 2018). In the studies conducted by Zhang et al. (2021) important findings were made regarding screen time and electronic device use, especially before sleep. The frequent use of alcohol by the person was found to be an important factor that increased both the time spent in front of the screen and the use of electronic devices before sleep. In addition to this study, Ren et al. (2023) also found in their study that long time spent in front of the screen is associated with an increased risk of stroke, which is more pronounced in men, and that the time spent in front of the screen should be limited to improve health. Hsueh et al. (2018) stated in their study that interaction with the environment is a very important factor for free-time physical activity and screen time. These findings suggest that policymakers and physical activity intervention designers need to develop both joint and individual environmental strategies to improve and increase awareness of the social environment to promote leisure-time physical activity and reduce screen time among older adults.

With the introduction of "screens" into our lives, peers and activities with peers have begun to be neglected and physical and mental health has begun to deteriorate. It is recognized that screen time is linked to sedentary behavior, especially among young people, and contributes to the increase in obesity, which is considered a risk factor in global mortality (Lissak, 2018; Domingues-Montanari, 2017; Li et al., 2020; Muppalla et al., 2023; Brzęk et al., 2021; Nakshine et al., 2022; Khouja et al., 2019; Abbasi et al., 2021; Ratan et al., 2020). Leisure activities, including physical, cognitive and social activities, are an important component of an individual's return to a healthy lifestyle. However, young people need to be supported in perceiving the benefits they can obtain from these activities. In this study, the perceived benefit level of students toward leisure activities preferred as exercise intervention was also examined. Thus, in order to increase the permanence of reducing screen time in mathematics students, it was aimed to continue their awareness after the program. Because physical activity should be a lifelong sustainable behavior rather than taking place in only one period of young people's lives. Mathematics department students, on the other hand, are distanced from exercise

both in their university life and in their professional life after university because they usually work at a desk and are exposed to the screen. Although education and working conditions are responsible for this distancing, it is also important that they are aware of the benefits they will get from leisure activities, which are preferred as exercise intervention in this research. For this reason, the first aim of this research is to reduce the excessive screen time of students continuing their education in the mathematics departments of universities with an exercise intervention, while the second aim is to examine the benefits that mathematics department students perceive from leisure activities with an exercise intervention.

2 Methods

2.1 Participants

The sample of this study consisted of 176 volunteer university students (58% female, 42% male) studying in mathematics departments at universities in Trabzon province in the 2023–2024 academic year. The demographic information of the participants is presented in the table below with their percentages.

The Table 1 shows the demographic characteristics of the study group and the distribution between the groups. The experimental group (EG) represented 48.3% of the participants, while the CG (CG) represented 51.7%. The proportion of female participants was 42.0% and the proportion of male participants was 58.0%. 57.4% of the participants were aged 21 years and younger and 42.6% of the participants were aged 22 years and older. When the Screen Viewing Time (SVT) of the participants is analyzed, 35.8% of the participants spent between 1 and 2 h looking at the screen, while 64.2% spent more than 2 h looking at the screen. It is observed that most participants look at the screen for more than 2 h.

2.2 Data collection scales and procedures

The Personal Information Form: This form includes the variables of gender, age and screen time of the participants. According to the data obtained from these variables, measurement tools such as screen time and leisure benefit scale were analyzed.

Screen Viewing Time (SVT): Based on the screen time limits set by the Canadian Pediatric Society, this scale records the responses to the question "How much time did you spend watching TV, Netflix, YouTube, Xbox, streaming video or anything else after school last week?." The scale includes the options "I have never done this activity," "more than 30 min," "30 min to 1 h," "1–2 h," and "2 h or more" (Canadian Paediatric Society, 2017). We scored the answers between 1 and 5 in order to analyze the screen time of mathematics students. A score of 1 corresponds to the answer that they are never exposed to the screen, while a score of 5 means that they spend more than 2 h a day on the screen. According to the Canadian Pediatric Society, a limit of 2 h per day has been set.

Leisure Benefit Scale (LBS): In order to measure leisure benefit levels, "The Leisure Benefits Scale," which was prepared and developed by Ho (2008) and whose Turkish adaptation, validity and reliability was carried out by Akgül et al. (2018) was applied. The LBS is a 5-point Likert-type scale and consists of 24 items and 3 factors. The rating is made as "Strongly disagree = 1, Strongly agree = 5." The Cronbach Alpha value of the scale is 0.83 and the internal consistency coefficients for the three sub-dimensions vary between 0.80–0.86. To determine the physical benefits perceived by the participants through the LBS, there are topics such as improving cardiopulmonary and physical fitness, protecting from diseases, having a good body shape, contributing to body development, helping to release energy, improving sleep quality, eliminating lethargy caused by daily work and helping to renew energy. To determine the psychological benefits, there are items such as relieve mental stress, to obtain a pleasurable mood, confirm his/her ability by leisure or sport activities, to develop his/her potential abilities, to be more satisfied with his/her life or work, cultivate an active personality to face challenges, to cultivate an independent personality, enjoy and learn new experiences and knowledge. To determine the social benefits, there are items such as improve relationships with my friends or peers, improve family harmony, establish the concept of teamwork, develop his/her social relationship and make new friends, trust from other participants in an activity, support from other participants in an activity understand the different feelings of other participants, share my opinion and thoughts with other participants, to improve my relationship with family and friends (Akgül et al., 2018).

Leisure Activities: The content of the exercise intervention determined to be applied to the EG of mathematics department university students was recreational. With the participation of all students, 3 different activities were organized in the gym for 2 h each 3 days a week. Rest was given the day after each activity. The exercise intervention was applied as basketball on Monday, Futsal on Wednesday and Volleyball on Friday. The attendance of the participants was recorded and 16 students who were absent for more than 2 weeks were excluded from the study.

TABLE 1 Demographic data.

Variables	Group	N	%
Study group	EG	85	48.3
	CG	91	51.7
Gender	Female	74	42.0
	Male	102	58.0
Age	≤ 21 years	101	57.4
	>21 years	75	42.6
Screen viewing time	1–2 h	63	35.8
	2 h+	113	64.2

2.3 Statistical analysis

The data analysis process with SPSS 25.0 was first evaluated using Kolmogorov–Smirnov tests to test whether normality was achieved. However, the results of these tests did not provide normality analysis. In this case, kurtosis and skewness values, another parameter of the normality indicator, were evaluated. According to Tabachnick et al. (2013), kurtosis and skewness values between −1.5 and + 1.5, which is an acceptable range for analysis, are suitable for parametric testing. Upon the failure to ensure normality, other parametric tests were analyzed. In this study, descriptive statistics, reliability analysis, t-test

for independent groups, and parametric tests for repeated measurements (Paired Sample T-test) were used. These analyses allow for deepening and interpretation of the analyses depending on the characteristics of the data set and the characteristics of the research questions. In the study, $p < 0.05$ was accepted as a criterion as an indicator of the significance level of data analysis. In the present study, Cohen's d values were used to measure the effect size in statistical analyses. In the interpretation of Cohen's d values, a value of 0.2 or less indicates a small effect size (S), 0.5 indicates a medium effect size (M), and 0.8 or more indicates a large effect size (L) (Cohen, 1988).

3 Results

Table 2 shows the arithmetic mean, standard deviation, kurtosis and skewness values of the participants' total and sub-dimensions of the LBS pre-test and post-test scores. When the kurtosis and skewness values of the pre-test and post-test scores of the total and sub-dimensions of the LBS of the participants were examined, it was determined that the data showed a normal distribution with kurtosis and skewness values between +1.5 and −1.5 and the data were suitable for analysis. When the arithmetic mean scores were examined, it was seen that the participants exhibited LBS scores above the average (Table 2).

According to the results of the t-test for independent groups applied to determine whether the participants' LBS pre-test scores were at a similar level between the groups (EG/CG), it was found that there was no significant difference between the EG and CG [$t_{(174)} = 0.25$, $p > 0.05$], (Table 3). In other words, it can be said that both the EG and CG participants who participated in the study had similar LBS scores.

In Table 4, the difference in the LBS scores of the individuals participating in the study was examined by t-test analysis applied for repeated measurements before and after exercise. There is a statistically significant difference between the LBS scores of the individuals participating in the research before and after the leisure activity and it is seen that the post-test scores have changed compared to the pre-test scores and the post-test scores have increased ($t = -14.88$, $p < 0.01$). When the sub-dimensions were examined, it was determined that the pre-test and post-test scores differed significantly in the physical ($t = -7.14$, $p < 0.01$), psychological ($t = -11.81$, $p < 0.01$) and social ($t = -10.67$, $p < 0.01$) dimensions, and there was an increase in the post-test LBS scores. When the LBS scores of the participants in the CG before and after the leisure activity were examined, it was seen that there was a statistically significant difference between the LBS scores and the post-test scores changed compared to the pre-test scores and the LBS scores decreased ($t = 6.57$, $p < 0.01$). In the context of sub-dimensions, it was found that the pre-test and post-test scores of the CG differed significantly in the physical ($t = 5.37$, $p < 0.01$) and social ($t = 8.47$, $p < 0.01$) dimensions, while no significant difference was found in the psychological ($t = 1.27$, $p > 0.05$) dimension. When the significant difference was analyzed, a decrease was observed in the post-test scores of the individuals in the physical and social dimensions. In other words, it can be said that the subject group increased their LBS scores by participating in leisure activities, while the CG decreased their LBS scores by not participating in leisure activities. After the Cohen's d analysis applied to determine the effect level of the significant difference, it was seen that the effect dimension was high in the subject group and medium in the CG.

The results of the t-test for repeated measurements applied according to the comparison results of the pre-test and post-test scores of the male and female participants in the EG and the CG are presented in Table 5. According to the results of this comparison, a significant difference was observed in the pre-test and post-test scores of the female and male participants in the subject group after the leisure activity, and a significant increase was observed in the post-test LBS total and sub-dimension scores ($p < 0.01$). When the pre-test and post-test scores of the CG female and male participants were examined, it was determined that there was a significant difference in the total and physical and social sub-dimensions of the LBS and the post-test scores decreased ($p < 0.05$), while the LBS scores did not change in the psychological dimension ($p > 0.05$). After Cohen's d analysis was applied to determine the effect size, it was seen that the effect size was strong in the subject group and moderate in the CG.

The t-test results for independent groups applied according to the pre-test and post-test score differences of the male and female participants in the EG and the CG are shown in Table 6. According to these results, no significant gender-related difference was detected in the pre-test and post-test score differences of the male and female participants in the subject group after the leisure activity ($p > 0.05$). When the pre-test and test score differences of the male and female participants in the CG were examined, it was determined that while there was no significant difference in the total, physical and psychological dimensions of the LBS ($p > 0.05$), the scores of the LBS changed in the social dimension ($p < 0.05$). It was found that this significant difference was due to the decrease in the post-test LBS scores of men compared to women in physical and social dimensions.

TABLE 2 LBS scale pre-test and post-test score descriptive statistics.

Test	Scales	No. of items	N	Min	Max	X	*sd*	Skewness	Kurtosis	Kol.-Smi.	Sha.-Wilk
Pre-test	LBS	24	176	2.75	4.13	3.69	0.32	−0.91	0.25	0.00	0.00
	Physical	8	176	2.50	4.38	3.48	0.35	0.01	0.70	0.00	0.00
	Psychological	8	176	2.25	4.63	3.65	0.47	−1.04	1.23	0.00	0.00
	Social	8	176	2.38	5.63	4.00	0.59	−0.55	0.86	0.00	0.00
Post-test	LBS	24	176	1.71	5.00	3.90	0.64	−0.47	0.40	0.00	0.00
	Physical	8	176	1.75	5.00	4.01	0.67	−0.69	0.70	0.00	0.00
	Psychological	8	176	2.38	5.63	4.19	0.81	−0.14	−0.58	0.03	0.01
	Social	8	176	2.50	4.50	3.61	0.50	0.15	−0.98	0.00	0.00

TABLE 3 Pre-test comparison of the participants.

Scales	Group	n	*X*	SD	df	t	*p*
LBS	EG	85	3.70	0.31	174	0.25	0.804
	CG	91	3.69	0.34			

When Cohen's d result was examined, it was determined that the significant effect was at a medium level.

The results of the t-test for independent groups applied according to the pre-test and post-test score differences of the participants in the subject and CGs who participated in the EG depending on the age variable are shown in Table 7. According to these results, no significant difference was found in the pre-test and post-test score differences of the participants in the subject and CGs after the leisure activity due to age ($p > 0.05$).

In Table 8, the difference in the screen viewing variable scores of the individuals participating in the study was examined with the t-test analysis applied for repeated measurements before and after exercise. A statistically significant difference was detected between the SVT scores of the EG before and after the leisure activity [$t_{(84)} = 7.32$, $p < 0.01$]. This significant difference indicates that the time spent looking at the screen by the participants in the subject group decreased before and after exercise. When the effect size impact is examined, it is seen that the effect size of the significant difference is high. When the SVT of the CG was examined, no significant difference was detected [$t_{(90)} = -1.52$, $p > 0.05$].

In Table 9, it was examined whether the difference scores of the individuals participating in the study in the scores of the variable of looking at the screen before and after the exercise created a significant difference according to gender with one-way ANOVA analysis. There was a statistically significant difference between the scores of looking at the screen in the EG before and after the leisure activity in both females [$F_{(1-72)} = 20.56$, $p < 0.01$] and males [$F_{(1-102)} = 20.29$, $p < 0.01$]. This significant difference indicates that the time spent looking at the screen decreased in both male and female participants before and after the exercise. When the effect size of the significant difference was analyzed, it was concluded that the effect size was strong.

4 Discussion

When we evaluate the results of the EG and CG participants, we see that there is a positive change in the first aim of our research, which is to reduce the excessive screen time of students continuing their education in the mathematics departments of universities with an exercise intervention. We see that there is a significant decrease in the screen time averages of the EG in the post-test data compared to the pre-test data. It was revealed that the EG participating in leisure activities decreased their screen time, while the CG not participating in leisure activities did not have a significant change in the screen time variable and their habits continued. From these results, it can be emphasized that exercise intervention is effective on screen time.

The second aim of our research, which is the benefit perceived by the mathematics department students participating in leisure activities, changed positively as a result of the examination of the RBF. In the EG, a significant increase was observed in the mean scores of the students who participated in leisure activities before and after the activity, while in the CG, which did not participate in the activities, a significant decrease was observed in the mean scores of the LBS in the opposite direction. The significant upward trend in all three of the physical, psychological and social benefit dimensions of the EG, which are the sub-dimensions of the LBS, shows that recreational activities transform the screen time habits of the person into physical, psychological and social benefits with physical activity activities.

Although the LBS scores of both groups before the recreational activities were above the average and there was no significant difference between them. The increase in the mean scores of the EG after the activities, the decrease in the CG and the significant difference between them reveal the usefulness of the activities. These results suggest that leisure programs have positive effects on participants and that these programs can provide beneficial results.

In the study conducted by Karaküçük et al. (2019) on orienteering athletes, it was stated that the RBF scores were at a medium level, the highest benefit score was in the physical dimension and the lowest benefit sub-dimension score was in the psychological dimension. It was stated that leisure activities provide very good physical, psychological and social benefits to adult individuals (Kurkcu Akgonul et al., 2023). Participation in leisure time activities is among the characteristics of social acceptance and the feeling of being able to communicate with each other more comfortably and more pleasantly, to relate equally and to be included in a group (Devine, 2004).

According to the findings of our study, we see that the biggest difference between the pre-test and post-test LBS score averages of the EG occurred in the social benefit sub-dimension. These results can be evaluated as the fact that team sports (basketball, volleyball, futsal) activities among the leisure activity types have a higher effect on socializing the person. When we look at the social benefit dimension, we see that the relationships of the EG participants with friends, peers and family members developed and improved after the leisure activities. The increase in the formation of the concept of teamwork, the development of social relationships and making new friends, the increase in the sense of trust toward others, the increase in the sense of receiving support from others and understanding the other person, the increase in sharing opinions and thoughts with others have emerged as important results in terms of social benefits. In fact, the EG participants gained an increase in their social aspects while reducing their screen time thanks to the leisure activities. This situation may have increased the level of self-awareness and psychological benefits. In fact, as a result of the LBS pre-test and post-test measurements in the EG, the sub-dimension with the highest change effect size was psychological benefits. The development of the participants' relationships with the people they communicate with may have reduced mental stress by channeling it in different directions. The development of understanding others and sharing thoughts comfortably may have created a pleasant mood. Experiencing the fulfillment of duties and responsibilities in team sports activities in a game environment may have increased the sense of awareness of their skills, and the variety of cooperation and communication during the game may have contributed to personality development. In the CG, when the pre-test post-test difference is examined, a decreasing significant change was observed mostly in the social benefits dimension, and no significant change was observed in the psychological benefits dimension, which is characterized by the late change process. Although there was no significant change in the CG's screen viewing time throughout the experimental process, an increase was observed. The significant decrease in the physical and social

TABLE 4 Comparison for LBS pre-test and post-test scores before and after the activity.

Group	Scale	Test	X	SD	X difference	SD difference	t	*p*	Effect size
EG (n:85)	LBS	Pre-test	3.70	0.31	−0.69	0.43	−14.88	0.001**	2.02 (L)
		Post-test	4.39	0.37					
	Physical	Pre-test	3.55	0.37	−0.41	0.53	−7.14	0.001**	1.05 (L)
		Post-test	3.96	0.41					
	Psychological	Pre-test	3.67	0.48	−0.79	0.62	−11.81	0.001**	1.77 (L)
		Post-test	4.46	0.41					
	Social	Pre-test	3.94	0.54	−0.81	0.70	−10.67	0.001**	1.38 (L)
		Post-test	4.74	0.62					
CG (n:91)	LBS	Pre-test	3.69	0.34	0.25	0.36	6.57	0.001**	0.60 (L)
		Post-test	3.44	0.48					
	Physical	Pre-test	3.41	0.33	0.13	0.24	5.37	0.001**	0.40 (M)
		Post-test	3.28	0.31					
	Psychological	Pre-test	3.63	0.47	0.04	0.33	1.27	0.207	null
		Post-test	3.58	0.59					
	Social	Pre-test	4.06	0.63	0.39	0.44	8.47	0.001**	0.63 (L)
		Post-test	3.67	0.60					

**$p < 0.01$ the significance level.

benefits dimension can be partially explained by the increase in the CG's screen viewing time.

Khan et al. (2023) examined the relationship between screen time and school performance in a total of 197,439 adolescents (13.6 ± 1.63 years; 51% girls) from Canada and 36 European countries and reported that more than 2 h of screen time per day began to negatively affect school performance. According to the results of the study, whether it is passive (i.e., television) or active (i.e., electronic games, computer use) screen time, as the duration increases, the negative effect on school performance increases in both genders, and it was suggested that reducing screen time will increase school performance.

Studies emphasizing the increase in screen time and decrease in participation in moderate-intensity activities during the pandemic period (Duncan et al., 2023) show that it has significant effects on habit change and habit acquisition, especially in children and adolescents.

The effects of increased screen time and decreased physical and social activities on human behavior, social structure, academic and work life success, and health are undoubtedly among the main problems of countries. In fact, as screen time increases, early effects may start to emerge physically and socially, but the fact that psychological effects are observed less or later does not mean that the problem is insignificant. Although there was no significant difference in the pre-test and post-test change in the psychological sub-dimension score of the LBS in the CG in our research results, the significant increase in the psychological benefit score in the EG reveals that physical activity makes people feel better in every aspect.

Chao (2013) reported a high relationship between leisure time participation, recreation benefit levels and happiness levels of 3,015 secondary school teachers. Koçyiğit et al. (2018) stated that "Socialization through recreation activities directly and significantly affects communication skills." Chiung et al. (2014) reported that leisure participation has a moderate effect on recreation benefit and motivation. Previous studies, which yielded parallel results to our study, show that people of all age groups and genders who participate in recreative activities and especially physical activities in their free time feel better, which leads to a sound psychological structure and an increase in social communication.

Participation in leisure time activities increases people's level of happiness (Chao, 2013), develops a sense of self-confidence (Kim et al., 2005), thus physical, psychological and social benefits emerge, and effective use of leisure time leads to leisure time satisfaction (Eskiler et al., 2019; Karoğlu and Atasoy, 2018). In fact, individuals who are aware that they use their free time efficiently are also aware of the benefits of these activities (Ayyıldız and Karaküçük, 2017; Ertüzün et al., 2020).

Although scientific studies have reported different results on the clarity of its effect, studies suggesting that physical activities such as moderate-intensity walking in free time to control hypertension reduce systolic and diastolic blood pressure in hypertensive patients, reveals the importance of free time activities in terms of health (Shariful et al., 2023).

In our study, we observed that participation in activities had a significant positive change in both genders. Although there was no significant difference between genders in the usefulness of participation in activities, male participants showed higher change in terms of physical and psychological benefits, while women showed higher change in terms of social benefits. In the CG, the significant decrease in LBS scores in both genders can be considered as the negative effect of not participating in leisure time activities. This decrease, especially in the physical and social benefit sub-dimensions, shows that men were more affected than women in terms of the social benefit sub-dimension. It is necessary to understand the gender-related effects of leisure activities in more detail and to examine the decreases in the CG in more detail. Some previous studies emphasize similar results of participation in leisure activities in terms of gender (Bülbül et al., 2021; Ertüzün et al., 2020; Karaküçük et al., 2019; Kocaer, 2019). In addition to some studies (Chao, 2013), it has been observed that women have disadvantages (such as time, knowledge

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TABLE 5 Comparison of LBS pre-test and post-test scores before and after the activity according to gender.

Gender	Group	Scale	Test	X	SD	X diff.	SD diff.	t	*p*	Effect size
Female	EG (n:37)	LBS	Pre-test	3.67	0.32	−0.69	0.43	−9.80	0.000**	1.88 (L)
			Post-test	4.36	0.41					
		Physical	Pre-test	3.55	0.37	−0.41	0.50	−4.96	0.000**	1.11 (L)
			Post-test	3.96	0.37					
		Psychological	Pre-test	3.68	0.50	−0.75	0.57	−7.94	0.000**	1.69 (L)
			Post-test	4.43	0.38					
		Social	Pre-test	3.86	0.52	−0.83	0.73	−6.88	0.000**	1.32 (L)
			Post-test	4.69	0.72					
	CG (n:37)	LBS	Pre-test	3.63	0.37	0.25	0.41	3.70	0.000**	0.49 (M)
			Post-test	3.38	0.62					
		Physical	Pre-test	3.28	0.34	0.07	0.22	2.06	0.049*	0.25 (S)
			Post-test	3.20	0.30					
		Psychological	Pre-test	3.53	0.54	0.02	0.36	0.28	0.780	null
			Post-test	3.51	0.71					
		Social	Pre-test	4.02	0.68	0.24	0.34	4.30	0.000**	0.73 (M)
			Post-test	3.78	0.67					
Male	EG (n:48)	LBS	Pre-test	3.72	0.31	−0.69	0.43	−11.08	0.000**	2.16 (L)
			Post-test	4.41	0.33					
		Physical	Pre-test	3.55	0.37	−0.42	0.56	−5.13	0.000**	1.00 (L)
			Post-test	3.96	0.44					
		Psychological	Pre-test	3.67	0.46	−0.82	0.65	−8.72	0.000**	1.84 (L)
			Post-test	4.49	0.43					
		Social	Pre-test	3.99	0.56	−0.79	0.67	−8.09	0.000**	1.45 (L)
			Post-test	4.78	0.53					
	CG (n:54)	LBS	Pre-test	3.72	0.31	0.25	0.33	5.56	0.000**	0.71 (M)
			Post-test	3.48	0.36					
		Physical	Pre-test	3.50	0.29	0.17	0.24	5.28	0.000**	0.58 (M)
			Post-test	3.33	0.30					
		Psychological	Pre-test	3.69	0.40	0.06	0.31	1.50	0.140	null
			Post-test	3.63	0.50					
		Social	Pre-test	4.09	0.60	0.49	0.47	7.66	0.000**	0.85 (L)
			Post-test	3.60	0.54					

*$p < 0.05$ and **$p < 0.01$ the significance level.

and economic status) in participating in recreative activities (Jackson and Henderson, 1995; Bittman and Wajcman, 2000). The results of the studies (Philipp, 1997; Ayhan et al., 2022), in which participation in recreative activities increased and women obtained a higher level of benefit than men, can also be considered in terms of socio-economic status variable or education level.

Previous research results generally show that men's physical activity participation levels in leisure-time activities are higher than women's, especially in moderate and high-intensity physical activities. The main reason for this difference is socio-economic level. As the development status of countries and the socio-economic level of individuals increase, leisure-time physical activity participation also increases. Socio-economic deficiency is based on both the lack of physical activity opportunities and the lack of information about leisure benefits. Another possibility may be due to the increased time spent in working life in low-income countries. In addition, when we look at the relationship between physical activity, gender and age, it is seen that physical activity participation decreases as age increases, more so in women (Azevedo et al., 2007).

The fact that there was no significant difference in our study in terms of age variable can be explained by the homogeneity of the age distribution of the participant group. These results suggest that the benefits of leisure activities of people in similar age groups have similar effects.

Physical activity contributes positively to life satisfaction, while personal internet use and TV consumption negatively affect life contentment and life satisfaction (Schmiedeberg and Schröder, 2017; Frey et al., 2019; Leung and Lee, 2005). In addition, based on the fact

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TABLE 6 Comparison of LBS pre-test and post-test scores before and after the activity according to gender.

Group	Scale	Gender	n	X	SD	df	t	*p*	Effect size
EG (n:85)	LBS	Female	37	0.69	0.43	83	−0.06	0.949	null
		Male	48	0.69	0.43				
	Physical	Female	37	0.41	0.50	83	−0.10	0.924	null
		Male	48	0.42	0.56				
	Psychological	Female	37	0.75	0.57	83	−0.50	0.618	null
		Male	48	0.82	0.65				
	Social	Female	37	0.90	0.78	83	0.58	0.565	null
		Male	48	0.81	0.73				
CG (n:91)	LBS	Female	37	−0.25	0.41	89	−0.02	0.988	null
		Male	54	−0.25	0.33				
	Physical	Female	37	−0.07	0.22	89	1.97	0.052	null
		Male	54	−0.17	0.24				
	Psychological	Female	37	−0.02	0.36	89	0.65	0.520	null
		Male	54	−0.06	0.31				
	Social	Female	37	−0.24	0.34	89	2.57	0.012*	0.52 (M)
		Male	54	−0.46	0.49				

*$p<0.05$ the significance level.

TABLE 7 Comparison of LBS pre-test and post-test scores before and after the activity according to age.

Group	Scale	Age	n	X	SD	df	t	*p*
EG (n:85)	LBS	≤ 21	48	0.63	0.44	83	−1.40	0.167
		> 21	37	0.76	0.40			
	Physical	≤ 21	48	0.35	0.54	83	−1.24	0.217
		> 21	37	0.49	0.52			
	Psychological	≤ 21	48	0.71	0.62	83	−1.28	0.204
		> 21	37	0.89	0.61			
	Social	≤ 21	48	0.84	0.79	83	−0.10	0.918
		> 21	37	0.86	0.69			
CG (n:91)	LBS	≤ 21	53	−0.27	0.43	89	−0.65	0.515
		> 21	38	−0.22	0.23			
	Physical	≤ 21	53	−0.12	0.25	89	0.67	0.506
		> 21	38	−0.15	0.22			
	Psychologial	≤ 21	53	−0.08	0.33	89	−1.16	0.250
		> 21	38	0.00	0.32			
	Social	≤ 21	53	−0.41	0.44	89	−1.02	0.310
		> 21	38	−0.32	0.46			

*$p<0.05$ the significance level.

TABLE 8 Comparison of SVT scores before and after the activity.

Group	SVT test	X	SD	X (diff.)	sd (diff.)	t	*p*	Effect size
EG (n:85)	Pre-test	1.55	0.50	0.41	0.52	7.32	0.000**	0.95 (L)
	Post-test	1.14	0.35					
CG (n:91)	Pre-test	1.73	0.45	−0.05	0.35	−1.52	0.132	null
	Post-test	1.78	0.42					

**$p<0.01$ the significance level.

TABLE 9 Comparison of pre-screening and post screening times of the study group according to gender.

SVT	Group	n	X	SD	df	F	*p*	Effect size
Female (n:74)	EG	37	−0.46	0.56	1–72	20.56	0.000**	1.05 (L)
	CG	37	0.05	0.40				
Male (n:102)	EG	48	−0.38	0.49	1–100	29.29	0.000**	1.08 (L)
	CG	54	0.06	0.30				

**$p < 0.01$ the significance level.

that those who do not have internet access are happier (Cuñado and de Gracia, 2012), it is necessary to understand the importance of recreative activities, especially those involving physical activity.

Our suggestion to other researchers is that supporting this importance with longitudinal and experimental studies and including demographic characteristics such as economic conditions, social status, welfare level, family education level, etc. in the study will further increase the importance of this study. If we touch on the weaknesses of the research, although there were 176 participants in the study, the fact that the participants came from a single field of expertise (mathematics) and a single province limits the generalization of the results. Expanding the research to include students in other fields and universities may yield more relevant and broadly applicable results.

According to our study results, it is very important to increase the habit and incentive to participate in leisure activities during the university student period, which is the most productive period of young people, in order to distract them from screen addiction and to ensure well-being fitness. Recreative activities are seen as an important tool to intervene in screen time. In addition to the physical and social effects that may show early symptoms, encouraging participation in activities is a very effective solution tool in order to prioritize the negativities of the psychological effects that occur later. It is predicted that if recreational activities, especially activities involving physical activity, are not made a habit at the ages in which the study is concerned, the individual will become more physically and psychologically worn out in the following years.

Data availability statement

The data supporting the conclusions of this article will be made available by the authors upon request. Requests to access the datasets should be directed to olcaymulazimoglu@mu.edu.tr.

Ethics statement

The studies involving humans were approved by Gümüşhane University "Scientific Publication and Ethics Committee. 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

ABÖ: Conceptualization, Methodology, Project administration, Supervision, Writing – original draft. OM: Conceptualization, Investigation, Project administration, Software, Writing – review & editing. MBS: Investigation, Project administration, Visualization, Writing – review & editing. FK: Investigation, Visualization, Writing – review & editing. ET: Data curation, Resources, Writing – review & editing. BA: Investigation, Resources, Writing – review & editing. HES: Data curation, Visualization, Writing – review & editing. ID: Data curation, Visualization, Writing – review & editing. OMO: Resources, 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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Effects of a 7-week active breaks intervention program on physical literacy and body mass index

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Introduction: Physical literacy (PL) emerges as a highly effective resource for creating lasting physical activity habits at a time when physical inactivity has become one of the main risk factors in our population. Thus, active breaks (AB) could be an ideal option for increasing physical activity time in schoolchildren.

Methods: A cross-sectional quasi-experimental study was conducted, involving 89 participants aged 8-12 years from Extremadura. The Canadian assessment of physical literacy (CAPL-2) was administered to assess the participants' physical literacy level. The BMI was also measured.

Results: Higher scores were obtained in all domains and subdomains of the CAPL in the experimental group. Significant differences were found both in total physical literacy score ($p < 0.001$) and in all domains and subdomains, except for the subdomains self-reported question, intrinsic motivation and knowledge and understanding domain ($p = 0.344$).

Conclusion: The results of the study support the positive effects of an AB program of PL and its domains. The development of active break programs could help to increase the PL level of schoolchildren.

KEYWORDS

physical literacy, active breaks, schoolchildren, CAPL-2, physical activity

1 Introduction

Physical inactivity has become the main risk factor in our population (Rezende et al., 2016; Bull et al., 2020) due to its contribution to the development of cardiovascular disease (Je et al., 2013), obesity, overweight, and diabetes (Bull et al., 2020; Michel et al., 2022). Despite this, the minimum physical activity (PA) guidelines and recommendations are clear that young people should engage in at least 60 min of moderate and vigorous physical activity per day, yet only than 20% of adolescents comply with these recommendations (WHO, 2021).

The promotion of healthy lifelong lifestyles justifies the use of resources to motivate and raise awareness of the reasons for and purposes for being more active (Frohlich and Potvin, 2008). Therefore, all interventions aimed at promoting PA should focus not only on the amount and intensity of physical activity (Cairney et al., 2019), but also on raising participants' awareness of why it is important to be active and to

maintain sustainable PA habits over time. Therefore, changes in behavior and PA habits will provide a healthier lifestyle, reducing levels of sedentary lifestyles in childhood and adolescence (Pate et al., 2011; Chaput et al., 2020), as well as diseases associated with physical inactivity, such as obesity, diabetes, or mental illness, with PA as the main tool to achieve this (van Sluijs et al., 2021). The importance of all this is heightened by the knowledge that children's elementary school years are a critical period for the development of long-term healthy lifestyles (Conti and Heckman, 2013), as habits formed in childhood are more likely to persist into adulthood (Pérez-Navero et al., 2018).

Physical literacy (PL) is emerging as a highly useful tool not only for promoting long-lasting habits of PA over time (Borchers and Pieler, 2010), but also for understanding why young people are or are not physically active (Whitehead, 2010). While physical activity is defined as "any bodily movement produced by the contraction of skeletal muscles that increases energy expenditure above the resting metabolic rate" (Caspersen et al., 1985, p. 127), PL is different and refers to an individual's understanding, knowledge, physical competence, motivation, and ability to be physically active on a sustained basis over time (Whitehead, 2010).

Nevertheless, there in undoubtedly a need to increase the amount of PA time for young people. Given its importance, active breaks (AB) could be an excellent option to increase children's physical activity during breaks from learning tasks (Howie et al., 2014), providing intention and commitment to physical activity during these periods (Bailey et al., 2024). This type of practice has increased through several strategies (Howie et al., 2014), promoting not only physical but also psychological outcomes (Erwin et al., 2014). Furthermore, a recent review revealed that ∼14% of PA interventions for children in Europe are based on AB (Porter et al., 2024). These interventions are mostly delivered during AB between classes, allowing them to be more active (McLellan et al., 2022). On the other hand, carrying out these activities during breaks in the school day (AB) could make a valuable contribution to promoting the practice of PA among schoolchildren (Hyndman, 2017).

Thus, the PA programs implemented during this period of time have shown how they help students to become more physically active, increasing not only the levels of physical activity but also the intensity with which the practice is performed (Ansón and García-Jiménez, 2017).

Currently, several studies have revealed how PL interventions have had positive effects on PL, both in extracurricular activities (Mandigo et al., 2019), and in physical education classes (Coyne et al., 2019). Studies on PL interventions during recess are scarce, but some studies implementing PA-based interventions have shown positive effects on PL (Mendoza-Munoz et al., 2022). Although no studies have been found that directly relate the positive effects of AB to PL, benefits of AB on academic performance (Petrigna et al., 2022), attention (Méndez-Giménez and Pallasá-Manteca, 2023), and concentration (Contreras Jordan et al., 2020; Fiorilli et al., 2021), wellbeing and PA habits (Petrigna et al., 2022; Peiris et al., 2022) have been reported. Thus, PL work during these periods could be highly beneficial for improving the domains of motivation (Méndez-Giménez and Pallasá-Manteca, 2023), physical competence, and daily physical activity time (Galle et al., 2020; Masini et al., 2020a).

Therefore, the aim of this study was to evaluate the effect of a 7-week AB intervention on PL and its domains in schoolchildren aged 8–12 years and to examine the body composition of participants before and after the intervention.

2 Material and methods

2.1 Study design

A cross-sectional quasi-experimental study with pre and post intervention assessments was designed to evaluate the effect of a 7-week PL based active breaks program.

2.2 Ethics

The research received the approval of the Bioethics and Biosafety Committee at the University of Extremadura (registral number: 91/2024), in accordance with the revisions made to the Helsinki Declaration by the 64th General Assembly of the World Medical Association (Fortaleza, Brazil, 2013) and in compliance with Law 14/2007 on Biomedical Research.

2.3 Procedures

Participants aged 8–12 years from three primary schools were recruited. The management team of the schools was contacted by e-mail and in person. To this end, the objectives and procedures of the study, the participants required, the test be conducted, and the duration and content of the intervention were explained to those responsible for each of the schools. The schools contacted the parents or guardians of the students, who decided whether or not their children would participate in the study. Once contact was established, authorization was obtained from the pupils' parents or guardians, and informed consent was obtained from the pupils themselves.

Prior to the start of the study, of the two classes selected from each center, one was randomly assigned to the experimental group (EG) and the other as the control group (CG). Both the assessments and the intervention were conducted by qualified personnel who were part of the study; school personnel did not participate in the study. Children in the CG only participated in the initial and final assessments. Participants in the CG performed free activities as in any normal recess. The children in the EG participated in the assessments and also in a program of active breaks based on physical literacy development for 7 weeks.

2.4 Participants

The final sample consisted of 89 participants, of which 49.4% were male and 50.6% were female. To be included in this study, the students needed to meet the following inclusion criteria: (1) age 8–12 years; (2) no pathology preventing physical activity; (3) informed consent from parents or legal guardians; (4) residence in Extremadura.

2.5 Intervention

This intervention was based on the study protocol developed by Mendoza-Muñoz et al. (2022). The theoretical and conceptual underpinning of this intervention focused on physical literacy, covering four distinct areas: physical competence, daily physical activity, knowledge and understanding, and motivation and confidence. The study lasted a total of 9 week, with the first and ninth weeks corresponding to the pre and post intervention assessment, respectively. During the remaining 7 weeks, the EG preformed a total of 21 physical literacy-based sessions, lasting 20 min, during the break period of the school day. On the other hand, the CG conducted the activities that the normally conducted in their daily lives during the school day, with the same timetable, frequency, and duration as the EG.

The sessions were divided into two distinct parts. The first part was aimed at working on knowledge content in an active way, through different activities such as orienteering races, relay races, or linking the answer (Table 1), where we work on content such as healthy lifestyle habits, benefits of physical activity, how to be more active, sports and their values, and basic physical capacities. On the other hand, during the second half of the session, a activity was played that remained constant throughout each week's sessions, but whose difficulty was progressively adjusted in each session, achieving a gradual increase in challenge during the week. This activity and its different variants were aimed at increasing the physical competence, motivation and confidence of the participants. The sports and games they participated in were *Mother Earth defender, Protect the pinnie, Keep it up, Farmers Shepherding Sheep, Tail chase, Switch it up, Knock Down*. These activities were obtained from PlaySport (Ontario Physical Health Education Association, 2022), initially developed by Ontario Physical and Health Education Association in partnership with Brock University. Each part lasted ~10 min, and each of the content was covered during the same week. The resources used were developed by the research team (Supplementary material S1).

For the development of the intervention and the presentation of results, the PLIRT guidelines established by Carl et al. (2023) for PL interventions have been considered (Supplementary Table S1).

TABLE 1 Activities and contents developed during the AB program.

	First part of session (10 min per day)		Second part of session* (10 min per day)	
Week	Activities	Activities Content	Activities	Objective
1	Physical literacy and body composition assessment			
2	Orientation relay	Physical lifestyle habits	Mother earth defender	Enhance physical competence, motivation and confidence
3	Orientation relay	Benefits of PA How to be more active?	Protect the pinnie	
4	Relay races	Sports skills	Keep it up	
5	Relay races	Type of sports	Farmers Shepherding sheep	
6	Link the answer	Kind of fitness (strength and endurance)	Tail chase	
7	Link the answer	Kind of fitness (speed and flexibility)	Switch it up	
8	Link the answer	All contents	Knock down	
9	Physical literacy and body composition assessment			

*All the activities belonging to the second part of the session were obtained from PlaySport (Association), initially developed by Ontario Physical and Health Education Association in partnership with Brock University.

2.6 Measures

In order to carry out the procedures, the study protocol Wellbeing, Obesity and Motricity Observatory (WOMO) (Mendoza-Munoz et al., 2020) was followed. The evaluation guide Canadian Assessment of Physical Literacy 2 (CAPL-2), developed by the Healthy Active Living and Obesity Research Group (HALO), belonging to the Children's Hospital of Eastern Ontario Research Institute (Heatlhy Active Living Obesity Research Group, 2017) in its Spanish adaptation was used for the assessment of the PL.

2.6.1 Anthropometry

Although no standardized data were used for the measurements, the conditions established by the OMS (de Onis et al., 2007) and the ALADINO study (Perez-Farinos et al., 2013) were followed. For the bodyweight measurement of participants' were measured without shoes and dressed in light clothing. A bioimpedancemeter (Tanita MC-780 MA, Tanita Corporation, Tokyo, Japan) was used. Weight was recorded in kg. Height was obtained using a height gauge (Tanita Tantois, Tanita Corporation, Tokyo, Japan), recorded in centimeters and approximation in millimeters. Participants stood with arms relaxed and feet balanced on a vertical surface, perpendicular to the ground.

To obtain the body mass index (BMI), the sex, age, and height of each participant were entered into the electrical bioimpedance device.

2.6.2 Physical literacy

The Canadian Assessment of Physical Literacy 2 (CAPL-2) was used for the assessment of the PL (Tremblay et al., 2018; Health, Economy, Motricity and Education Research Group (HEME) and Promoting a Healthy Society Research Group, PHSO; Longmuir et al., 2018a). The scores ranges from 0 to 100 points, resulted from the sum of its four domains. Each domain is composed of different test, obtained a final score of each of them. The domains of PL are: physical competence, daily physical activity behaviors, knowledge and understanding and motivation and confidence.

1. Physical competence domain (PC domain). It allows to evaluate the physical competence of the participants. This domain consists of three tests, each one evaluated from 1 to 10 points, obtaining a final score for this domain out of 30 points. These tests are:

    a) Isometric abdominal plank during 2 min (Longmuir et al., 2018b).
    b) Progressive aerobic cardiovascular endurance run "PACER." Capacity cardiorespiratory test.
    c) Canadian Agility and Movement Skill Assessment "CAMSA." Agility circuit.

2. Daily physical activity behavior (DB domain). The final score of this domain is obtained from the number of total daily steps of the participant recorded through an activity wristband (Xiaomi mi Band 3, Xiaomi Corporation, Pekin, China), and the number of minutes of physical activity performed by the participants for at least 60 min.
3. Knowledge and understanding (K&U domain). To obtain the score for this domain, participants answer five questions, scoring up to 10 points. Four of the five question scored 0 or 1 each, while the last question is a fill in the blanks question in a story, scored from 1 to 6 points.
4. Motivation and confidence (M&C domain). This domain attempts to measure participants' confidence and motivation to be physically active. Its score ranges from 1 to 30 points. It consists of four parts: intrinsic motivation, competence, predilection and adequacy.

2.7 Statistical analysis

Statistical procedures and calculations were performed using Statistical Package for the Social Sciences (SPSS, version 25.0; IBM SPSS Inc., Armonk, NY, USA). Data are presented as mean and standard deviation (SD) or median and interquartile range (IR) for variables with normal and non-normal distributions, respectively. Shapiro-Wilk and Levene's tests were used to test the normality and homogeneity of the data. Then, inferential tests were performed for all dependent variables. A two-way repeated measures analysis of variance (ANOVA) was performed to examine the interaction between two factors: group (experimental and control) and two timepoints (baseline, post-intervention) in all dependent variables. Significant differences were set at $p \leq 0.05$.

3 Results

The characteristics of the participants in both the control and experimental groups are shown in Table 2. No significant differences were found between the control and experimental groups for any of the anthropometric variables or for age ($p = 0.168$; $p = 0.508$).

Table 3 shows the BMI and CAPL-2 scores for both the control and experimental groups, as well as the intergroup and intragroup differences.

Regarding the experimental group, all domain and subdomain scores of the CAPL were higher in the post-intervention assessment than pre-intervention. Significant im-provements were found in total PL ($p < 0.001$), as well as in all domains and subdomains except self-reported question ($p = 0.085$), Intrinsic motivation ($p = 0.617$) and K&U domain ($p = 0.344$).

About intergroup differences, the results reported no differences between the control and experimental groups in the pretest, except for the CAMSA test, where the score was higher in the control group than in the experimental group ($p = 0.002$). In the case of the post-test, significant improvements were detected in the experimental group with respect to the control, in the M&C domain and its subdomain's predilection and adequacy.

No intergroup or intragroup differences were reported for BMI.

4 Discussion

The concept of PL has become a highly relevant and widely researched concept in recent years (Gilic et al., 2022), and has become a fundamental concept for schoolchildren's participation in a wider range of physical activities (Caldwell et al., 2020). Currently, several studies of PA programs have reported changes in PL levels of participants. These studies were conducted during Physical Education classes (Kriellaars et al., 2019) as well as during after-school activities (Mandigo et al., 2019; Bremer et al., 2020). However, only one study protocol was found that addressed the

TABLE 2 Total sample characteristics and stratified by group.

	All participants	Experimental group ($n = 43$)		Control group ($n = 46$)		Between-group comparison
Gender		Male	Female	Male	Female	
N (%)	89 (100)	21 (48.8)	22 (51.2)	23 (50)	23 (50)	
	Median (IR)	Median (IR)		Median (IR)		*p*
Age (years)	11 (2)	11 (2)		10 (2)		0.508
Weight (kg)	39.60 (43.3)	42.8 (43.3)		39.15 (29.3)		0.209
BMI (kg/m^2)	18.85 (17.01)	19.02 (15.73)		18.40 (14.6)		0.426
	Mean (SD)	Mean (SD)		Mean (SD)		
Height (cm)	146.18 (8.30)	147.47 (9.31)		144.98 (7.50)		0.168

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TABLE 3 Outcome of BMI and physical literacy measures at baseline and post-intervention.

	Experimental group ($n = 43$)					Control group ($n = 46$)						
	Baseline		Post-intervention		Within-group	Baseline		Post-intervention		Within-group	Between group pre	Between group post
	Mean	SD	Mean	SD	*p*	Mean	SD	Mean	SD	*p*	*p*	*p*
BMI	19.82	4.00	19.76	4.01	0.667	18.93	3.44	18.97	3.56	0.763	0.260	0.330
DB domain (points)	17.070	1.117	19.814	1.104	<0.001	19.304	1.080	19.370	1.067	0.927	0.154	0.773
Self-reported question (points)	3.581	0.208	3.907	0.164	0. 085	3.587	0.201	4.065	0.158	0.010	0.985	0.489
Diary steps (points)	13.488	1.032	15.907	1.033	0.001	15.717	0.998	15.304	0.999	0.545	0.124	0.676
PC domain (points)	15.821	0.885	19.360	0.828	<0.001	17.261	0.856	18.458	0.800	0.032	0.245	0.435
CAMSA (points)	5.332	0.268	6.919	0.238	<0.001	6.522	0.259	6.871	0.230	0.099	0.002	0.886
Plank (points)	6.907	0.509	7.837	0.433	0.025	6.804	0.492	7.413	0.419	0.126	0.885	0.483
PACER (points)	3.581	0.310	4.605	0.373	<0.001	3.935	0.300	4.174	0.361	0.348	0.415	0.409
M&C domain (points)	25.912	0.432	27.421	0.464	0.003	25.630	0.418	25.000	0.448	0.196	0.641	<0.001
Predilection (points)	6.784	0.167	7.233	0.167	0.020	6.889	0.162	6.546	0.162	0.063	0.652	0.004
Adequacy (points)	6.814	0.192	7.374	0.154	0.016	6.524	0.185	6.270	0.149	0.253	0.279	<0.001
Intrinsic motivation (points)	6.453	0.151	6.535	0.146	0.617	6.293	0.146	6.283	0.141	0.945	0.448	0.217
Competence (points)	5.860	0.158	6.279	0.148	0.013	5.924	0.153	5.902	0.144	0.892	0.773	0.071
K&U domain (points)	6.535	0.263	6.837	0.233	0.344	6.587	0.254	6.957	0.226	0.232	0.887	0.714
Overall physical literacy (points)	65.337	1.899	73.433	1.814	<0.001	68.783	1.836	69.784	1.754	0.350	0.195	0.152

BMI, Body mass index; DB, daily behavior domain; PC, physical competence domain; CAMSA, Canadian Agility and Movement Skill Assessment; PACER, Progressive Aerobic Cardiovascular Endurance Run; M&C, motivation and confidence domain; K&U, knowledge and understanding domain.

effects of an active breaks program on physical literacy, on which this study is based (Mendoza-Munoz et al., 2022).

The present study aimed to evaluate the effects of a 7-week active breaks intervention on PL and its domains in schoolchildren aged 8–12 years, also analyzing participants' body composition before and after the intervention. The results obtained reveal that the program was effective in improving general PL and in several specific domains, except for the K&U domain ($p = 0.334$), in which the EG scored higher than the CG, although without significant differences.

Activity during active breaks in the school day has been shown to be an excellent way to improve the health of schoolchildren, both in terms of reducing body fat, increasing speed and coordination (Aguilar-Jurado et al., 2020), as well as improving cognitive performance (Latorre-Román et al., 2021). In this sense, Vicedo et al. (2021) concluded that these periods represent valuable opportunities to increase children's physical activity time and help them reach the minimum recommended levels of healthy PA.

Because of its importance, it is inevitable to think about how AB could be used to improve health and, with it, the time dedicated to physical activity of schoolchildren. If we review systematic studies on AB (Vicedo et al., 2021), we find numerous interventions aimed at promoting PA, however, those that address the importance of AB to improve PL are less frequent. Promoting PL is critical, given its

impact on health. Nevertheless, when considering the benefits of AB interventions, one could find and ideal tool and space to help schoolchildren adop a healthy lifestyle through PA and PL.

Although there are currently different tools that can assess the PL in schoolchildren, Shearer et al. (2021), in their systematic review of PL assessment tools, highlighted that the CAPL-2 is currently the most robust explicit assessment instrument at present, demonstrating validity and reliability in the assessment of PL. Thus, several studies have attempted to give visibility to the assessment of PL in schoolchildren in different countries through the CAPL-2 (Dania et al., 2020; Mendoza-Munoz et al., 2024; Hadier et al., 2024; Elsborg et al., 2021; Knisel et al., 2024; Li et al., 2020; Longmuir et al., 2015), showing that the level of PL in this population is low or "in progress" (Li et al., 2020; Longmuir et al., 2015; Dania et al., 2020).

Analyzing the evolution of each of the domains in both groups after the intervention, we can observe that in the DB domain, significant differences were found in the EG ($p < 0.001$), but not in one of its subdomains, despite obtaining a higher score in the post-assessment (Self-reported question; $p > 0.05$). Our results differ from those found by Mendoza-Munoz et al. (2022) who, in their 4-week study, found no significant improvements in this domain, which could be due to the duration of the intervention or to the contents of the intervention itself. On the other hand, Masini et al. (2020b), in their 14-week study of active breaks, showed significant improvements in the number of weekly steps taken by their participants. Similarly, Torrandell and Vidal-Conti (2021) found that those schoolchildren who were more active during breaks had a greater number of hours of physical activity during the week.

Therefore, the EG in our study may have increased significantly in this domain after receiving more encouragement to engage in daily physical activity, relative to the CG, and the duration of the intervention may be entirely relevant in empowering and stimulating participants sufficiently to increase their daily and weekly physical activity time. The fact that significant differences were found in a more objective test such as the number of steps participants took per week, compared to a more subjective test such as answering a self-reported question about the number of days they were physically active, may support the idea that the intervention time was sufficient to motivate students to increase their daily steps, but not to make them aware that by doing the activities during breaks, they were simultaneously increasing the number of days they were physically active. Future interventions based on AB should further investigate the long-term effects on participants's daily physical activity routines.

On the other hand, the EG obtained significant improvements in the PC domain and its subdomains, in contrast to the CG, which did not obtain significant improvements in any of the subdomain but did obtain significant improvements in the final score of the domain. One possible explanation for this could be that each of the subdomains achieves higher scores, though not sufficient to yield significant improvements individually. Therefore, these improvements might have accumulated to influence the overall score of the domain, resulting in a significant change in the global computation.

The significant differences found in the EG in this domain may be due to the relationship between PL, health, and fitness (Caldwell et al., 2020). In this way, PL becomes a determining factor in the development of children's physical fitness (Gilic et al., 2022). Increasing pupils' motor engagement time during active breaks, through activities that promote the development of cardiorespiratory capacity, strength, and agility may be fundamental for their development. In this regard, Mendoza-Munoz et al. (2022) reported significant improvements in this domain, as well as in the CAMSA and PACER subdomains. These results, similar to those observed in our study, could also have been influenced by the association demonstrated in various studies between the general level of PL and cardiorespiratory capacity (Lang et al., 2018) and agility (Mandigo et al., 2019). Thus, the significant improvements in the general level of PL might have contributed to advancements in this domain and its subdomain.

Regarding the M&C domain, our results show significant differences in the total score of the domain and its subdomains for the EG. However, in the subdomain of intrinsic motivation, no significant differences were found for this group ($p = 0.617$). Furthermore, a significant increase was also observed in the EG compared to CG after the intervention. Therefore, this domain could become the most relevant factor for children to reach the minimum recommendations for physical activity (Belanger et al., 2018), since both the motivation of students to be active and the place of activity have a positive influence on increasing their activity (Lang et al., 2018). In this regard, several physical activity-based interventions (Abós et al., 2016), and PL (Bremer et al., 2020) have reported improvements in motivation level, reflected in a willingness to participate in a greater number of physical activities and sports after their interventions (Bremer et al., 2020).

No significant improvements were found in the knowledge and understanding domain, although a positive trend was observed in the EG. The literature has shown that knowledge about physical activity is an essential component of the cognitive domain of PL (Gilic et al., 2022), although its direct effects on physical activity practice are still unknown. However, several studies have shown positive relationships of this domain with PC (Li et al., 2020) and M&C (Li et al., 2020; Knisel et al., 2024). Due to the influence of PA on the children's cognitive performance (Reloba et al., 2016), it could be that due to the low intensity of the task proposed during the intervention, or the short time spent performing PA daily, no significant differences were found in this domain (Luque-Illanes et al., 2021). In addition, the limitations of the intervention may have been insufficient to facilitate understanding and retention of the knowledge necessary for children to recognize the value of physical activity in their lives. This opens up a line of future research where future studies could investigate the importance of knowledge and understanding of physical activity and its practice, as well as explore whether the intervention time is limited to achieve meaningful learning.

In terms of body composition, no significant differences in BMI were found in either group, highlighting the importance of a longer intervention duration to observe substantial changes in this variable (Henaghan et al., 2008). However, given that several studies have reported differences in students' PL levels as a function of BMI (Delisle Nystrom et al., 2018; Mendoza-Munoz et al., 2021), further

research should study the long-term effects of physical literacy on schoolchildren and explore the benefits of physical literacy on schoolchildren's body composition.

One of the main strengths of this study is that it allows us to know and support the findings found by Mendoza-Munoz et al. (2022) about the benefits of implementing active breaks programs on PL in schoolchildren. However, the main difference with respect to that study is not only the duration, but also in the type of activities and content addressed throughout the intervention. In addition, the use of the CAPL-2 to measure the PL in schoolchildren allows it to be assessed in a comprehensive and objective manner in its different domains. Therefore, the findings of this study have important applications for health promotion, physical education, and educational policy. The implementation of this type of program could help not only to improve PL, but also to know the level of PL of schoolchildren, making it possible to take measures in the different intervention programs by adapting them to the needs of all students, since a child with a low level of PL will tend to avoid physical activity as much as possible, will have little confidence in their physical capacity and will not be motivated to participate in structured physical activities (Tremblay et al., 2018), therefore, physical literacy in all schoolchildren will be fundamental.

4.1 Limitations

The main strength of this study is the use of an objective assessment of physical literacy, validated for assessment in schoolchildren between 8 and 12 years of age (Longmuir et al., 2018a). However, this study has several methodological limitations that need to be carefully considered. Firstly, the sample size ($n = 89$) is relatively small for a study of this nature, which could affect the statistical power and consequently the detection of significant effects, especially in those subdomains where no significant differences were found (self-reported questions, intrinsic motivation and knowledge and understanding domain). This limitation becomes particularly relevant when analyzing the effects in specific age subgroups within the studied range (8–12 years). The selection of the sample by convenience, limited to schools in Extremadura, is another substantial limitation that affects the external validity of the study. The specific characteristics of the Extremadura context, including its socio-economic, cultural and educational particularities, could differ significantly from other Spanish regions or international contexts. This geographical and contextual specificity limits the generalizability of the results to other school populations with different socio-demographic characteristics, educational resources or pre-existing physical activity programmes. The duration of the active-break intervention represents another significant limitation. Although positive effects were found on the total physical literacy score and in most domains and subdomains, the intervention period was not long enough to assess the sustainability of these effects in the medium and long term. This temporal limitation is particularly relevant in the context of physical literacy, where the main goal is to create lasting physical activity habits. The absence of longitudinal follow-up prevents us from determining whether the observed gains in physical literacy levels are maintained beyond the immediate intervention period or whether these changes actually translate into sustainable physical activity habits.

5 Conclusions

The results of this study support the positive effects on physical literacy and its domains of an activity-based active breaks program covering all domains. In contrast to other studies, this work was notable for the duration and specific focus of the activities and for the application of the CAPL-2 for a comprehensive assessment of physical literacy domains. These findings have important implications for the design of intervention programs and the formulation of educational policies that promote physical literacy and health in schoolchildren. The implementation of active breaks could contribute to improving the level of PL in students, which is crucial to prevent physical inactivity in those with low confidence and motivation to engage in structured physical activity.

In conclusion, active breaks programs specifically designed to improve physical literacy offer a promising avenue for strengthening physical health and engagement in physical activity in schoolchildren. Future studies could focus on interventions of longer duration and in different contexts to explore the long-term effects on children's physical behavior and body composition, thus facilitating the adoption of active and healthy lifestyles from an early age.

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 the research received the approval of the Bioethics and Biosafety Committee at the University of Extremadura (registral number: 91/2024), in accordance with the revisions made to the Helsinki Declaration by the 64th General Assembly of the World Medical Association (Fortaleza, Brazil, 2013) and in compliance with Law 14/2007 on Biomedical Research. 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 minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

JU-M: Investigation, Writing – original draft, Writing – review & editing, Project administration, Validation. LM-B: Conceptualization, Supervision, Writing – review & editing. JC-V: Data curation, Methodology, Writing – review & editing. RP-C:

Conceptualization, Project administration, Writing – review & editing. JM-E: Formal analysis, Supervision, Writing – review & editing. MM-M: Conceptualization, Investigation, Methodology, 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.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2025.1535729/full#supplementary-material

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Applying virtual reality to sail education: an innovative strategy to enhance knowledge learning for student novices

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Background: Sailing has been proved beneficial for physical and mental health promotion, which has made it a prevalent sport among children and adolescents. Nevertheless, the existing pedagogical strategies cannot satisfy students' demands for learning. To bridge this gap, virtual reality (VR) is considered an innovative approach to addressing the challenges in sailing education.

Objective: The study aimed at designing an education program to examine effectiveness of VR technology in sail knowledge learning.

Methods: University students with no prior experience or knowledge in sailing were recruited and randomly allocated to either experimental group (N = 32) using VR in lectures and self-practice or control group (N = 34) attending traditional lectures. The sail education program consisted of 12 sessions over 6 weeks. Sailing knowledge test was developed from an official manual by American Sailing Association to assess outcomes of learning in overall performance, sailboat structure, sailing skills, and navigation rules. The Situational Motivation Scale (SIMS) was used to assess the constructs of intrinsic motivation, identified regulation, external regulation, and amotivation. A 2 × 2 MANOVA was conducted for statistical analysis.

Results: Both groups improved accuracy rate after the program, with significant time effects in all outcome measures. Particular advantages of VR were identified in facilitating knowledge learning on sailing skills and navigation rules. Significant interaction effects suggest that application of VR induced greater improvement than traditional lectures. Comparable performance between the two groups was found in sailboat structure, with non-significant results in group effect and interaction effect. What's more, VR could better improve students' intrinsic motivation and identified regulation while better reduce external motivation and amotivation in sailing lessons.

Conclusion: The findings verified feasibility of applying VR to promote sail education for student novices. To enhance effects of VR in teaching and learning, course design should focus on reflective connections between knowledge and experience, which stimulate students in active, engaging, and insightful learning.

KEYWORDS

sailing, virtual reality, novice, physical education, randomized controlled trial

1 Introduction

Long ago, sails carried humans across the oceans in quest of discovery, wealth, and power. As time goes by, it has been discovered that sailing carries great value in personal development and education. A multinational qualitative study showed that sail training is a powerful educative experience having a special benefit in developing social confidence for young people (McCulloch et al., 2010). To further explore the impact of sailing on children, researchers conducted a qualitative study of a small sailing program with 38 children (9–13 years old). Semi-structured interviews and focus groups on children, teachers, and sailing instructors identified the main benefits of dinghy sailing in physical and mental health, development of key life skills, self-esteem, and academic performance (Cotterill and Brown, 2018). As well, a quasi-experimental study involving 147 adolescents found that even a short sail training activity can significantly improve participants' Social and Competence self-concept (Capurso and Borsci, 2013). A comprehensive meta-analysis indicated that sailing, as one of the adventure sports, has a positive impact on leadership, self-concept/self-esteem, locus of control, interpersonal attitudes, physical fitness, and environmental awareness (Hattie et al., 1997). While the sport has many benefits, factors such as high cost, complicated skills, and geographical restraints make it a niche sport whose participants are mainly professional athletes. To provide more people with the opportunity to access and learn the sport, experts have suggested promoting sailing into schools as a formal education, thereby breaking down geographical and economic constraints (Schmitt et al., 2020). This approach can ensure planned, systematic, comprehensive, and large-scale lessons, effectively selecting and developing sailing talents. According to the 5-year plan (2021–2025) released by the Chinese government, it is expected that by 2025, in Qingdao, the number of sailing-featured schools will be increased to 132 and the number of students learning basic sailing knowledge will reach 22,000 (Qingdao, 2021).

However, designing and implementing sailing lessons under physical education (PE) settings remains challenging for practical reasons. Unlike athletes with rich knowledge and skillful performance over longitudinal training, students in PE classes have no or limited previous sailing experience. Improving the skill proficiency of the novices by sailing on the sea may raise concerns about time efficiency, cost, and safety. For the programs that begin with theory learning, the abstract knowledge can be difficult for novices to understand without hands-on practice. To better satisfy students' demands for more active, engaging, and insightful learning, there are researchers innovating pedagogical strategies. An experimental study involving 80 students found that the flipped classroom teaching model can greatly enhance participants' satisfaction level and academic knowledge of sailing (Caraballo Vidal et al., 2024) while it created a huge workload for teachers and students to find textual information, thus reducing the effectiveness of instruction. Another quantitative study showed that teaching races for understanding (TRFU) can be used in sailing to improve students' capacity to reflect and connect theoretical knowledge with their motor performance in the race (Morales-Belando and Arias-Estero, 2017). Yet, this program was limited by space and weather and not suitable for large-scale teaching. Therefore, helping more students visualize task-related situations and corresponding operations in safe, interactive, and controlled environments is an effective way to solve the existing problems.

Virtual reality (VR) is considered an innovative approach to addressing the challenges in sailing education (Ji et al., 2023). This technology provides a powerful tool for implementing situated learning perspective and cognitive theory of multimedia learning. It can present theoretical knowledge in the form of 3D practical scenarios (Plotzky et al., 2021) or simulated lifelike learning situations allowing users to immersively interact with virtual objects, thus reducing cognitive load and stimulating imagination to assist the mind's capacity to conceptualize. In addition, VR is the perfect complement to other practical classes and enables faster skill acquisition and better retention. On the one hand, characteristics such as immersive experience, first-person perspective, and self-paced task constraints make VR technology feasible for accelerating the transition from procedural knowledge to practical skills, which has led to its wide application in many sports. For example, in training baseball batting, VR can simulate real batting situations and provide adaptive baseball training involved performance-based adjustments of pitch speed, pitch type, and location, to improve athletes' perceptual-motor skills (Gray, 2017). Similarly, in basketball offensive tactics (Tsai et al., 2022) and table tennis (Oagaz et al., 2022) technical training, VR can also provide realistic training environments to help athletes improve their tactical understanding and reaction speed, thus showing greater adaptability and competitiveness in the face of complex real-world tasks. On the other hand, in a safe virtual environment, students can repeat the actions that are not easy to perform in practical situation as many times as they like, thus building muscle memory and leading to longer retention. Furthermore, VR technology has been shown to be effective in increasing student motivation (Garris et al., 2002), interaction, and active engagement (Roussou, 2004) in other educational settings and subjects.

The unique features of sailing compared to other sports, such as intricate sailboat structures, complex navigation rules, and dynamic environmental factors, make it an ideal candidate for VR-based instruction. The immersive and interactive characters of VR can potentially enhance students' understanding and retention of sailing concepts, skills, and strategies. Although some researchers have recognized the potential of VR-based sailing education in teaching practice (Wu et al., 2020), the scientific community still lacks an in-depth understanding of how VR technology can specifically promote the effectiveness of sailing knowledge learning in a physical education (PE) setting. Currently, relevant studies still remain in the theoretical exploration stage, lacking rigorous experimental design and systematic effect evaluation to accurately judge the practical application value of VR technology in sailing education. To fill this research gap, the current study develops a VR-based sailing education program and designs a randomized controlled trial to evaluate its effectiveness compared to traditional sailing lectures. Academic performance (which encompasses overall sailing knowledge, sailboat structure understanding, sailing skills, and navigation rule knowledge) and motivation (including intrinsic motivation, identified regulation, external motivation, and amotivation) were used as indicators of learning outcomes in this study, because the former reflects students' mastery of sailing knowledge and skills, while the latter underlies behavior and can influence persistence, effort, and overall success in learning (Ryan and Deci, 2020). Our primary focus was on testing the following core hypotheses:

> *H1*: Compared with the traditional approach, VR technology can be more effective in improving student novices' overall sailing

TABLE 1 Differences between groups at the baseline.

Category	EG (M ± SD)	CG (M ± SD)	*p*-value
Sailing knowledge (%)	45.72 ± 7.19	42.03 ± 9.02	0.07
Sailboat structure (%)	31.25 ± 10.70	28.24 ± 11.41	0.27
Sailing skills (%)	46.06 ± 9.57	44.85 ± 11.42	0.64
Navigation rules (%)	62.69 ± 14.89	62.50 ± 18.46	0.96
Intrinsic motivation	16.44 ± 5.91	14.76 ± 5.67	0.25
Identified regulation	16.34 ± 4.96	14.76 ± 6.14	0.26
External regulation	17.72 ± 6.42	20.18 ± 3.95	0.18
Amotivation	16.56 ± 7.47	19.38 ± 4.29	0.07

EG, experimental group; CG, control group; M, mean; SD, standard deviation.

knowledge, sailboat structure, sailing skill, and navigation rule knowledge.

H2: Compared with the traditional approach, VR technology can be more effective in improving student novices' autonomous motivation.

By testing these hypotheses, the study aims to contribute valuable insights into the effectiveness of VR-based sailing education and its potential to improve learning outcomes in PE settings. The results of the study can inform educators and researchers about the potential benefits of integrating VR technology into sailing education, and contribute to the development of more effective and engaging teaching methods in the field, thereby promoting the popularity of sailing and enabling more individuals to reap its benefits.

2 Materials and methods

2.1 Participants

A total of 68 undergraduate students from Qingdao University in China were recruited as participants (age = 18.42 ± 1.084; female = 36, male = 32). The sample size was determined by a prior power analysis at α level of 0.05, power (1—β) of 0.80 (Faul et al., 2009), and 10% of drop rate (Zhang et al., 2023). Eligible participants should meet the following criteria: (1) good health and free of vertigo, (2) normal or corrected to normal vision, (3) no sailing knowledge and experience, and (4) no schedule conflicts with the class. Recruitment information was predominantly disseminated by flyers and social media. Additional approach included emails and presentations at classes. This study was approved Ethics Committee of Qingdao University, and the collected data were processed anonymously. Written informed consent was obtained from all participants.

The participants were randomly allocated to experimental group (EG, $N = 34$) and control group (CG, $N = 34$) by a computer-based random number generator. Before the intervention, however, two participants in EG missed the pre-test and the first lesson because of flu, resulting in 32 participants in EG. Independent sample *t*-test was conducted to identify potential between-group differences at the baseline. The results indicated that all *p*-values were greater than 0.05, suggesting no significant difference in prior knowledge between both groups (Table 1).

2.2 Study materials and apparatus

The sailing courses were designed in accordance with the book, Sailing Made Easy, which is American Sailing Association's official manual of basic sailing standards (American Sailing Association, 2010). Content of chapters 1, 3, 5, 6, and 7 was taught in six sessions for both groups. Specifically, critical points covered in the sessions included the points of sail, structure of a sailboat, momentum control, turning the boat, docking, and safe sailing, etc. A prominent advantage of the book was the review questions presented at the end of each chapter, which provided essential references to develop sail knowledge test.

The VR headset applied to the intervention was Meta Quest 2 head mounted display (HMD). This device has raised researchers' interest because of its portability and convenience to use. It is a wireless standalone device which is independent of a computer and external tracking system (Trinidad-Fernández et al., 2023). The VR courses were conducted by means of a virtual sailing game, MarineVerse Cup (Virtual Reality Sailing Pty Ltd., Melbourne, Australia). Utilizing VR headsets, this fully immersive app can provide extensive 3D sailing tutorials on different sailboat models, navigation rules, and sailing skills which provide a good match with the textbook content. Table 2 summarizes the tutorial modules of the VR game in correspondence to the book chapters.

2.3 Outcome measures

2.3.1 Sailing knowledge test

To assess the prior knowledge before the intervention (i.e., pre-test), and achievement following the intervention (i.e., post-test), an online sailing knowledge test was developed with the following procedures. Firstly, three experts were invited to adapt 40 multiple-choice questions from textbook to construct the initial test. Secondly, 14 respondents who had attended the traditional lectures were invited to participate in the pilot test. Based on classic test theory (CTT), we analyzed that the test has satisfactory validity and reliability. The discrimination indices of all 40 items ranged from 0.33 to 0.86, which means there was no need for further revision because greater than

TABLE 2 Tutorial modules of the VR game in correspondence to the book chapters.

Tutorial modules	Book chapters
Sailboat structure	Chapter 1
Parts of sailboat	
Sailboat's Rig	
On-board orientation	
Sailing skills	Chapters 3, 5, and 7
Tacking	
Jibing	
Using spring lines	
Docking	
Navigation rules	Chapter 6
Buoys and marks	
Stand-on and give-way rules	

0.30 was considered acceptable (Lien, 1971). The difficulty indices with a mean value of 0.59 clustering around 0.50, support this test has good discrimination power (Brookhart and Nitko, 2011). The reliability coefficient of Cronbach's alpha was 0.732 which was within the acceptable level of reliability (range 0.70–0.80) (Nunnally and Bernstein, 1994). Eventually, all 40 questions were included in the final paper. Accuracy rate was the measure of performance, and a higher rate implies a favorable learning outcome.

2.3.2 Situational motivation scale

In order to understand students' current (or state) self-regulatory processes in different sailing classes, the English version of Situational Motivation Scale (SIMS) (Guay et al., 2000), which has good reliability and factorial validity in a PE context among adolescents (Østerlie et al., 2019), was used in this current study. Based on the self-determination theory (SDT) (Deci and Ryan, 2000), the SIMS assesses a more diverse range of types of motivation, namely intrinsic motivation, identified regulation, external regulation, and amotivation, which significantly overcomes the limitations of traditional measures, such as the free-choice measure and self-report questionnaires (Guay et al., 2000). This scale comprises a total of 16 items, systematically organized into four subscales, each containing four items. Notably, the Cronbach's alpha values for these four subscales ranged from 0.77 to 0.95, indicating robust internal consistency and reliability. Respondents were asked to indicate their level of agreement on this 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Their chosen number was then converted into a corresponding score, with all items scored positively.

2.4 Study design and procedures

The current study adopted a randomized controlled design for 12 h of sail knowledge learning. EG completed 6 h of VR lectures and 6 h of self-directed practice. In the VR sessions, an instructor gave a lecture while a teaching assistant collaborated by wearing the VR headset to present the first-person view of sailing (Figure 1).

Self-directed practice was arranged as a review session after each lecture. Students made an appointment with a research assistant according to availability of the device. By taking advantage of after-school hours, the students practiced the content of previous lecture in a VR-simulated environment. Each review session was conducted under supervision of a teaching assistant who was responsible to provide instructions and technical support during practice.

Control group provided novices with only lecture-based classes for 12 sessions over 6 weeks. In the lectures for CG, the same content was covered as EG. The instructor used slides, pictures, and videos to assist in understanding.

All participants completed the sailing knowledge test and SIMS online within 45 min in pre- and post-test. To ensure integrity in the tests, behaviors such as page refreshes, copy and paste, and communication with others were not allowed during the test. After each test, the system automatically collected the questionnaires while ensuring data security and privacy protection. Figure 2 illustrates procedures of the research project.

2.5 Data analysis

A 2×2 repeated measures multivariate analysis of variance (MANOVA) was conducted to analyze the main effect of time, intervention, and the interaction effect on sailing knowledge and situational motivation. Independent variables include both between-group factor (Group: EG vs. CG) and within-group factor (Time: pre-test vs. post-test). Dependent variables in sailing knowledge are overall performance in sail knowledge test and individual categories of knowledge on sailboat structure, sailing skills, and navigation rules while in motivation are intrinsic motivation, identified regulation, external motivation, and amotivation.

Data points beyond three standard deviations from the mean were defined as outliers. Normality assumption was examined by the Shapiro–Wilk test. Levene's test of equality of error variances was performed to verify homogeneity of variance assumption. Statistical significance was defined by the cutoff point of 0.05. Partial eta squared (η^2) measured effect size, with 0.01, 0.06, and 0.14 defining small, moderate, and large effects (Cohen, 1988). All statistical analyses were conducted by SPSS 25.

3 Results

3.1 Effect of teaching methods on sailing knowledge

Significant improvement in overall sailing knowledge was found for both groups after the 6-week sail education program, which was evidenced by the main effect of time, $F(1, 64) = 1162.52$, $\eta^2 = 0.95$, $p < 0.001$. It is worth noting the significant group effect, $F(1, 64) = 27.43$, $\eta^2 = 0.30$, $p < 0.001$. Despite similar performance in the pre-test (EG: 45.72%, CG: 42.03%, $p = 0.07$), students taking VR-based lectures outperformed their counterparts receiving traditional lectures in the post-test (EG: 93.91%; CG: 84.19%, $p < 0.001$). The interaction effect also reached the significant level, $F(1, 64) = 5.17$, $\eta^2 = 0.08$, $p = 0.03$, indicating that VR-based lectures induced greater improvement than traditional lectures.

FIGURE 1
Demonstration of the VR-based lecture.

The subsequent analyses focused on each category of the sailing knowledge. Specifically, knowledge regarding sailboat structure improved by the end of the program, which was substantiated by the significant main effect of time, $F(1, 64) = 1027.70$, $\eta^2 = 0.94$, $p < 0.001$. Both EG (pre-test: 31.25%, post-test: 93.13%, $p < 0.001$) and CG (pre-test: 28.24%, post-test: 91.18%, $p < 0.001$) indicated significant improvement in the post-test. The main effect of group was non-significant, $F(1, 64) = 1.69$, $\eta^2 = 0.03$, $p = 0.20$, indicating similar performance between the two groups. Additionally, interaction effect was non-significant, $F(1, 64) = 0.08$, $\eta^2 = 0.001$, $p = 0.79$, suggesting comparable performance change over time.

Knowledge on sailing skills was learned after the program due to the significant main effect of time, $F(1, 64) = 677.08$, $\eta^2 = 0.91$, $p < 0.001$. Both EG (pre-test: 46.06%, post-test: 94.03%, $p < 0.001$) and CG (pre-test: 44.85%, post-test: 81.55%, $p < 0.001$) showed a higher accuracy in the post-test. The main effect of group was statistically significant, $F(1, 64) = 17.47$, $\eta^2 = 0.21$, $p < 0.001$. VR-based learning resulted in a favorable outcome to traditional lectures in the post-test (EG: 94.03%, CG: 81.55%, $p < 0.001$). The magnitude of improvement was greater in EG compared with CG, which was supported by a significant interaction effect, $F(1, 64) = 12.00$, $\eta^2 = 0.16$, $p = 0.001$.

In terms of knowledge on navigation rules, significant results were identified in the main effect of time, $F(1, 64) = 90.58$, $\eta^2 = 0.59$, $p < 0.001$, indicating a higher accuracy in the post-test. VR technology facilitated understanding of navigation rules. This can be substantiated by significant group effect, $F(1, 64) = 7.98$, $\eta^2 = 0.11$, $p = 0.01$, and favorable performance associated with EG in the post-test (EG: 94.53%, CG: 82.72%, $p < 0.001$). A significant interaction effects was identified, $F(1, 64) = 4.52$, $\eta^2 = 0.07$, $p = 0.04$, indicating that VR technology induced a greater improvement than traditional lectures (Table 3).

3.2 Effect of teaching methods on motivation

Compared with traditional lectures, VR induced greater improvements in students' intrinsic motivation and identified regulation but larger reductions in external motivation and amotivation.

In intrinsic motivation, the main effect of time was significant, $F(1, 64) = 16.82$, $\eta^2 = 0.21$, $p < 0.001$. Both EG (pre-test: 16.44, post-test: 20.22, $p = 0.003$) and CG (pre-test: 14.76, post-test: 17.97, $p = 0.009$) showed a higher intrinsic motivation in the post-test. The main effect of group was also statistically significant, $F(1, 64) = 4.97$, $\eta^2 = 0.07$, $p = 0.03$. Further analysis found a higher level of intrinsic motivation associated with VR-based learning than traditional lectures in the post-test (EG: 20.22, CG: 17.97, $p = 0.03$). Additionally, interaction effect was non-significant, $F(1, 64) = 0.11$, $\eta^2 = 0.002$, $p = 0.74$, suggesting comparable performance change over time.

The identified regulation indicated similar outcomes to the intrinsic motivation. The main effect of time was significant, $F(1, 64) = 14.96$, $\eta^2 = 0.19$, $p < 0.001$, suggesting an overall improvement in the post-test. The group effect was also statistically significant, $F(1, 64) = 4.48$, $\eta^2 = 0.07$, $p = 0.04$. There was no significant difference between EG and CG in the pre-test ($p = 0.26$), but EG outperformed CG in the post-test at a statistically significant level (EG: 19.91, CG: 17.65, $p = 0.04$). The interaction effect was non-significant, $F(1, 64) = 0.17$, $\eta^2 = 0.003$, $p = 0.69$, suggesting comparable performance change over time.

In external motivation, significant results were identified in the main effect of time, $F(1, 64) = 13.23$, $\eta^2 = 0.17$, $p = 0.001$, as well as the main effect of group, $F(1, 64) = 9.20$, $\eta^2 = 0.13$, $p = 0.003$. No significant result was observed in interaction effect, $F(1, 64) = 0.002$,

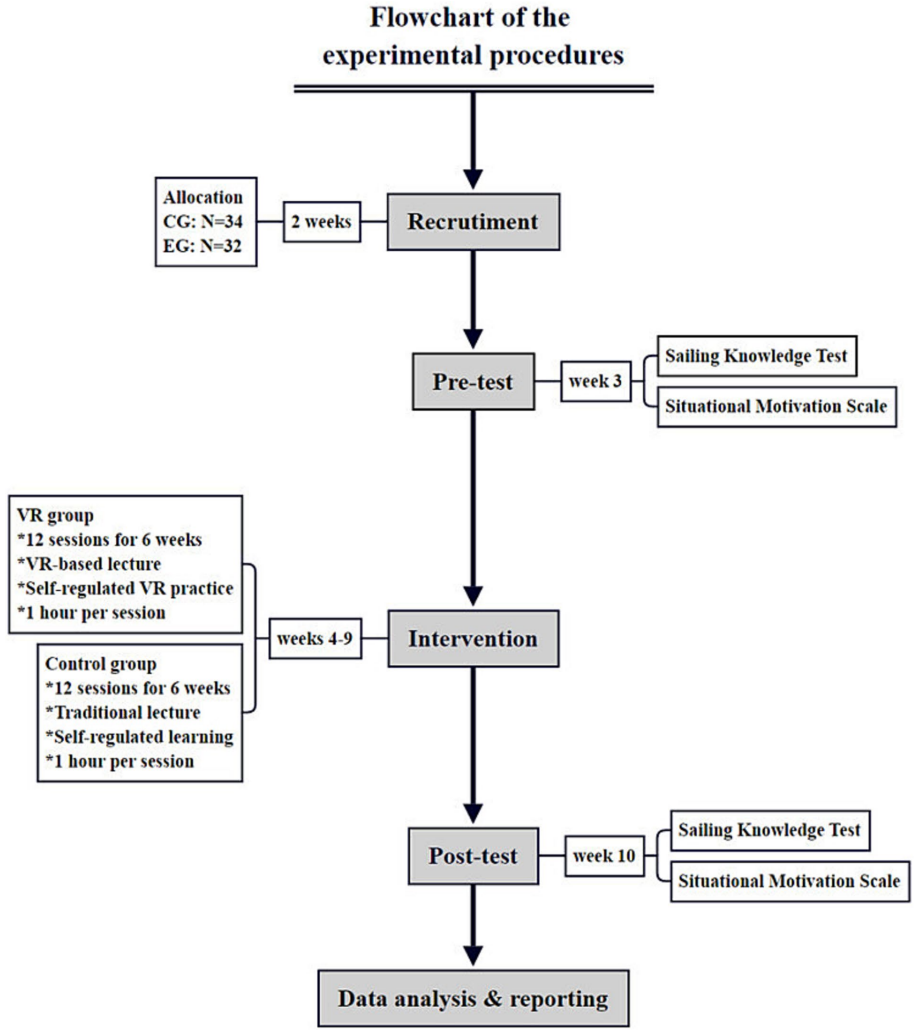

FIGURE 2
Flowchart of the experimental procedures.

TABLE 3 Academic performance in sailing knowledge tests.

Category	Time	EG	CG	Two-way MANOVA		
		M ± SD	M ± SD	Time effect	Group effect	Interaction effect
Sailing knowledge (%)	Pre	45.72 ± 7.19	42.03 ± 9.02	$F = 1162.52$ $\eta^2 = 0.95$ $p < 0.001$	$F = 27.43$ $\eta^2 = 0.30$ $p < 0.001$	$F = 5.17$ $\eta^2 = 0.08$ $p = 0.03$
	Post	93.91 ± 5.08	84.19 ± 7.92			
Sailboat structure (%)	Pre	31.25 ± 10.70	28.24 ± 11.41	$F = 1027.70$ $\eta^2 = 0.94$ $p < 0.001$	$F = 1.69$ $\eta^2 = 0.03$ $p = 0.20$	$F = 0.08$ $\eta^2 = 0.001$ $p = 0.79$
	Post	93.13 ± 9.98	91.18 ± 12.00			
Sailing skills (%)	Pre	46.06 ± 9.57	44.85 ± 11.42	$F = 677.08$ $\eta^2 = 0.91$ $p < 0.001$	$F = 17.47$ $\eta^2 = 0.21$ $p < 0.001$	$F = 12.00$ $\eta^2 = 0.16$ $p = 0.001$
	Post	94.03 ± 6.37	81.55 ± 9.29			
Navigation rules (%)	Pre	62.69 ± 14.89	62.50 ± 18.46	$F = 90.58$ $\eta^2 = 0.59$ $p < 0.001$	$F = 7.98$ $\eta^2 = 0.11$ $p = 0.01$	$F = 4.52$ $\eta^2 = 0.07$ $p = 0.04$
	Post	94.53 ± 8.36	82.72 ± 12.32			

EG, experimental group; CG, control group; M, mean; SD, standard deviation.

$\eta^2 < 0.001$, $p = 0.96$. However, it is worth noting that the external motivation reduced in the post-test whether in the VR group (pre-test: 17.72, post-test: 14.19, $p = 0.01$) or the control group (pre-test: 20.18, post-test: 16.74, $p = 0.01$). Students in EG had lower external motivation than in CG after the sail education program (EG: 14.19, CG: 16.74, $p = 0.04$).

Consistent findings with the external motivation were identified in amotivation. The main effect of time, $F(1, 64) = 13.91$, $\eta^2 = 0.18$, $p < 0.001$, and the main effect of group, $F(1, 64) = 14.96$, $\eta^2 = 0.19$, $p < 0.001$, were statistically significant. In contrast, the interaction effect was non-significant, $F(1, 64) = 0.54$, $\eta^2 = 0.008$, $p = 0.47$. Further analyses found significant reductions in autonomous motivation after the intervention in both EG (pre-test: 16.56, post-test: 12.09, $p = 0.003$) and CG (pre-test: 19.38, post-test: 16.38, $p = 0.04$). No significant difference was found between EG and CG in the pre-test ($p = 0.06$). In the post-test, however, students in EG had lower autonomous motivation than their counterparts in CG (EG: 14.19, CG: 16.74, $p = 0.001$) (Table 4).

4 Discussion

Participants improved basic sail knowledge after 6-week courses given by either VR sessions or traditional lectures. It is necessary to highlight the favorable outcomes associated with VR learning. EG showed a higher accuracy rate than CG in overall knowledge in the post-test, and the magnitude of improvement is significantly larger than CG. Specifically, VR technology facilitated understandings on sailing skills and navigation rules, which was substantiated by preferable performance of VR-based sessions over traditional lectures in the post-test. In addition to the differences between the teaching approaches, comparable performance was identified in terms of knowledge on sailboat structure. Therefore, the main findings provided critical insights into applying VR technology to course design and teaching.

The current study is consistent with a recent meta-analysis revealing that HMD-based immersive learning has an overall better effect on learning performance than non-immersive learning approaches (Wu et al., 2020). According to the experiential learning theory, "learning is the process whereby knowledge is created through the transformation of experience" (Kolb, 1984). The VR-based sail education program was designed in line with the four-step cycle of experiencing, reflecting, thinking, and acting. Authentic feeling was simulated by the first-person view, 3D modeling, spherical video, and virtual field trips (Weyhe et al., 2018; Chien et al., 2020; Han, 2020). A prominent advantage of VR-based lectures over traditional lectures is the concrete experience in learning. Additionally, VR-based lectures associated with demonstration in a virtual environment facilitated students making reflective connections between teaching content and observation. The reflective observation then helped the students to engage in thinking to comprehend concepts, form theories, and reach conclusions. After each VR-based lecture, self-regulated learning sessions were assigned which provided students with affordances of learning by doing. In this stage, the students tested their theories and thoughts through active experimentation, thus establishing direct connections between operations and outcomes. The enhanced learning effects can be also explained by embodied learning theory, which highlights the relationship between body movements and cognitive processes (Smith, 2024). Adding a motoric modality to the learning signal can activate more neural paths, which can make learning signals or memory tracking stronger (Kim et al., 2023).

An example that describes the learning process is the understanding of no-sail zone. "A sailboat can barely make any forward progress directly into the wind. When you tried to sail close to the wind, the sails simply flapped and you lost headway." This interpretation is probably what students always heard about no-sail zone in traditional lectures. In the virtual environment, students are given the sailor role to trim the virtual sail and then can actually see how speed changes when the sailboat approaches, enters and leaves the zone. In terms of upwind sailing, the smaller the angle between the boat and the wind direction, the slower the speed. By observing the prominent change in speed, students can better understand the concept of no-sail zone. Therefore, explorations in the virtual environment enhance learning by doing.

Situational motivation refers to the motivation that an individual experiences while currently engaged in an activity (Vallerand, 1997). This concept provides valuable insights into an individual's current self-regulation processes. To further refine

TABLE 4 Motivation performance in SIMS tests.

Category	Time	EG	CG	Two-Way MANOVA		
		M ± SD	M ± SD	Time effect	Group effect	Interaction effect
Intrinsic motivation	Pre	16.44 ± 5.91	14.76 ± 5.67	$F = 16.82$ $\eta^2 = 0.21$ $p < 0.001$	$F = 4.97$ $\eta^2 = 0.07$ $p = 0.03$	$F = 0.11$ $\eta^2 = 0.002$ $p = 0.74$
	Post	20.22 ± 3.20	17.97 ± 4.62			
Identified regulation	Pre	16.34 ± 4.96	14.76 ± 6.14	$F = 14.96$ $\eta^2 = 0.19$ $p < 0.001$	$F = 4.48$ $\eta^2 = 0.07$ $p = 0.04$	$F = 0.17$ $\eta^2 = 0.003$ $p = 0.69$
	Post	19.91 ± 3.86	17.65 ± 4.70			
External regulation	Pre	17.72 ± 6.42	20.18 ± 3.95	$F = 13.23$ $\eta^2 = 0.17$ $p = 0.001$	$F = 9.20$ $\eta^2 = 0.13$ $p = 0.003$	$F = 0.002$ $\eta^2 < 0.001$ $p = 0.96$
	Post	14.19 ± 5.15	16.74 ± 4.80			
Amotivation	Pre	16.56 ± 7.47	19.38 ± 4.29	$F = 13.91$ $\eta^2 = 0.18$ $p < 0.001$	$F = 14.96$ $\eta^2 = 0.19$ $p < 0.001$	$F = 0.54$ $\eta^2 = 0.008$ $p = 0.47$
	Post	12.09 ± 3.60	16.38 ± 5.93			

EG, experimental group; CG, control group; M, mean; SD, standard deviation.

and describe the situational motivation, self-determination theory (SDT) divides motivation into four components including intrinsic motivation (IM), identified regulation (IR), external regulation (ER) and amotivation (AM), which constitute a self-determination continuum from high to low levels (Deci and Ryan, 1991). The results obtained through the 7-point Likert scale in the current study showed that students' IM and IR increased to a larger extent associated with VR sailing. On the other hand, greater reductions ER and AM were identified in EG compared to CG. Specifically, VR captured students' inherent interest and enjoyment in learning about sailing, thereby enhancing their IM (Deci and Ryan, 2000). IM is a critical component of self-determination theory and is likely responsible for the preponderance of human learning across the lifespan (Bouffard et al., 2017). In formal education, IM has been shown to predict student engagement and, in turn, higher achievement (GPA) (Froiland and Worrell, 2016). Therefore, the increase in IM associated with VR sailing can be seen as a positive outcome that may lead to improved learning and engagement among students. The increased IR means that students consciously identified with or personally endorsed the value of the sailing activity and experienced a relatively high degree of volition or willingness to act (Ryan and Deci, 2020). IR is a form of motivation that is more autonomous and self-determined than ER. Therefore, the increase in IR associated with VR sailing can be seen as a positive outcome that may lead to more sustained engagement and effort among students. Notably, the study found that ER decreased in the EG compared to the CG. ER concerns behaviors driven by externally imposed rewards and punishments and is typically experienced as controlled and non-autonomous (Ryan and Deci, 2020). The significant decrease in ER in the EG suggests that VR was able to reduce the reliance on external rewards and punishments among students, which may lead to more autonomous and self-determined motivation. Additionally, the study also found that AM decreased in the EG compared to the CG. AM can result from a lack of felt competence to perform or a lack of value or interest in the activity. It has been shown to be a strong negative predictor of engagement, learning, and wellness (Ryan and Deci, 2020). The decrease in AM in the EG suggests that VR was able to address some of the underlying issues that may have contributed to AM among students, such as a lack of interest or competence in sailing. This, in turn, may lead to improved engagement and learning among students. In conclusion, these findings suggest that VR-based education can facilitate increasing students' self-determination and lead to improved learning and engagement among students.

These results are significant for future PE programs, especially sailing education. By providing immersive and interactive learning experiences, VR can help students develop a strong foundation in sailing skills and knowledge. This can make the transition to real sailing smoother and more effective. In addition, the engaging and enjoyable nature of VR can stimulate students' interest in sailing and motivate them to further explore and engage with the sport. Despite the promising results, the study has several limitations that should be noted. For example, the sample size of the study was relatively small, which may limit the generalizability of the findings to larger populations. Besides, the sail education program consisted of 12 sessions over 6 weeks. It is unclear whether the benefits of VR-based learning would persist over longer periods of time or with more extensive use of the technology. Furthermore, this study only explored the impact of VR on students' theoretical sailing knowledge, which is an important starting point, but clearly not sufficient to fully assess the effectiveness of VR in the field of sailing education. Therefore, in future research, it is essential to combine VR-based learning with real-world practice to ensure that students develop comprehensive and practical sailing skills.

5 Conclusion

Sailing is considered effective in promoting health, life skills, self-esteem, and academic performance for children and adolescents. The current study compared VR lectures with traditional lectures in the effectiveness of students learning basic sail knowledge and motivation. Participants attending the VR lectures and self-regulated VR practice outperformed their counterparts taking traditional lectures in the post-test. Specifically, VR technology induced superior outcomes over traditional lectures in sailing skills, and navigation rules. An evidence-based conclusion can be reached that VR is an effective instrument to facilitate student novices learning basic sail knowledge. Compared with traditional lectures using sailboat model to introduce structure of a sailboat, VR sessions indicated no advantage. The finding implies that VR facilitates learning by helping the students to make observable and reflective connections between abstract knowledge and experience. Because VR could better improve students' intrinsic motivation and identified regulation while better reduce external motivation and amotivation in sailing lessons. According to self-determination theory, it can be further deduced that VR-based sailing education facilitates increasing students' self-determination. In conclusion, we suggest that VR is a promising supplement to traditional teaching methods, providing students with an active, engaging, and insightful learning experience. However, it cannot currently serve as a complete substitute for real-world sailing. This is because the existing VR technology is unable to replicate certain sensory elements, such as the feel of the wind, the smell of the sea, and the physical sensation of movement, all of which are important to the sailing experience.

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 Qingdao 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. 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

SZ: Writing – original draft, Writing – review & editing. FJ: 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

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Physical-intellectual badminton teaching intervention for children with intellectual disabilities

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Objective: To promote the healthy development of adolescents with intellectual disabilities, this study uses badminton to combine sports intervention with cognitive intervention to explore the content of sports teaching and cognitive intervention programs suitable for the learning of students with intellectual disabilities.

Methods: This research selected 26 mildly mentally disabled students in special education schools (age: 14.5 ± 0.8 years old), the subjects were randomly assigned to three groups by the digital randomization method, which badminton physical intelligence group (BSI), badminton group (BS) and control group (CON), with BSI conducting "physical intelligence" integration badminton intervention, and BS conducting badminton intervention, the intervention cycle was 12 weeks, with 3 teaching sessions per week, each session lasted for 40 min. The subjects' cognitive abilities and basic motor skills were analyzed.

Results: The results showed that BSI had highly significant differences in all cognitive ability test items ($p < 0.01$); BS had significant differences only in visual attention, visual memory, and motor imitation ($p < 0.05$). The results of incremental changes between groups before and after the intervention showed that BSI compared with CON had significant differences in all aspects except in object constancy ($p < 0.05$); BS compared with CON had higher incremental means than CON in visual attention, visual memory, and movement imitation, with significant differences ($p < 0.05$); BSI compared with BS had significant differences in all aspects except in object constancy and visual memory aspects, there is a significant difference ($p < 0.05$).

Conclusion: The "Body-Smart Integration" badminton intervention can improve the cognitive ability of students with intellectual disabilities in visual, auditory, imitation, concept learning, object permanence, etc., and the effect of improving the cognitive ability of students with intellectual disabilities is better than that of the badminton group and the control group.

KEYWORDS

intellectual, disability, "physical intelligence" fusion, cognitive ability, physical quality, basic movement skills

1 Introduction

In special education today, the education and development of students with intellectual disabilities have become increasingly prominent (Morgan et al., 2015). This is caused by environmental or genetic influence of the patient's genetic (gene) system abnormal production of a mental development before birth, during birth or early life stages due to various reasons are hindered and stop the development of comprehensive symptoms. Mildly retarded people have poor learning ability and discounted ability to adapt to life, mainly in the inability to understand problems correctly, unable to think flexibly, and slow to solve problems (Prokhorenko and Makarov, 2022). Owing to congenital or acquired deficiencies, they generally face multiple challenges, such as poor physical fitness, low levels of cognitive ability, and lagging levels of motor skill development, which not only seriously affects the quality of their daily lives but also dramatically restricts their ability to integrate into society (Kaya and Cavkaytar, 2021). With the increased attention paid to the cause of special education and the introduction of a series of policies and regulations, how to effectively promote the healthy physical and mental development of students with intellectual disabilities and improve their social adaptability has become an urgent issue in the field of special education (Maenner et al., 2021; Baio et al., 2018).

Faced with the problem of lagging physical and mental development of students with intellectual disabilities, researchers have conducted numerous explorations and studies. Previous studies have shown that physical education and sports interventions have significant effects in enhancing the physical fitness and motor skills of students with intellectual disabilities, while cognitive interventions help to improve their cognitive abilities (Carraro and Gobbi, 2014; Stanish and Temple, 2012; Ginis et al., 2021; Robertson et al., 2018; Jacinto et al., 2021).

As a popular and exciting sport, badminton can not only effectively exercise physical fitness and improve motor skills but also cultivate quality and promote interpersonal skills, which positively affects the physical and mental health development of students with intellectual disabilities (Latino et al., 2018). Therefore, this study combines badminton with cognitive training and explores the positive effects on the physical and mental development of students with intellectual disabilities by integrating the "physical and intellectual" teaching intervention model.

Firstly, a "physical and intellectual" integrated badminton teaching intervention model for students with intellectual disabilities will provide new ideas and methods for physical education teaching in special schools (Trollor et al., 2018). This model will consider the characteristics of students with intellectual disabilities, fully consider their physical conditions and cognitive levels, and develop a targeted teaching program (Page and Cannella-Malone, 2019).

Secondly, through empirical research, we verified the positive effects of badminton's "physical and intellectual" integration on the physical fitness, motor skills, and cognitive abilities of students with intellectual disabilities (Fu et al., 2024). By comparing the data before and after the experiment, we can evaluate the effect of the intervention and provide a scientific basis for the Practice of special education.

Finally, the badminton teaching intervention program and the specific implementation content are formulated to suit the students with intellectual disabilities by considering their characteristics. This will help improve the teaching quality of special schools and promote the overall development of students with intellectual disabilities.

Therefore, this study aims to explore the positive impact on the physical and mental development of students with intellectual disabilities through the integration of badminton's "physical and intellectual" pedagogical interventions to contribute to developing the cause of special education. By constructing a teaching intervention model suitable for students with intellectual disabilities, verifying its effectiveness, and developing corresponding implementation contents, this study will provide new ideas and methods for the Practice of special education and promote the comprehensive development of students with intellectual disabilities.

2 Materials and methods

2.1 Research population

Twenty-six mildly intellectually disabled students aged 13–16 were selected as subjects for this experiment. Through the test results of basic motor skills, physical fitness, and cognitive ability in the pre-experimental period, the students were grouped into badminton physical and intellectual group (BSI, $n = 9$), badminton group (BS, $n = 8$), and control group (CON, $n = 8$). The badminton physical and intellectual group was provided with 12 weeks of physical-intellectual integration of badminton teaching and learning interventions, the badminton group was provided with 12 weeks of badminton teaching and learning interventions, and the control group does not provide any instructional or specifically organized exercise interventions. In the other two badminton teaching groups, except for the specially organized badminton intervention program, no organized sports (such as sports classes, sports games, etc.) are provided, but the normal physical activities of the subjects are not restricted. Any intervention was carried out, with one 40-min classroom session thrice weekly. The relevant local ethics committee approved the study, approval no: SY-ZQ-2024-122. This study conducted the grouping of subjects in accordance with the method of randomized controlled trials. In brief, each subject was numbered using a random number generator on a computer and randomly assigned to one of the three groups. The calculation method of sample size of subjects referred to previous studies and combined with the characteristics of this study, SAS Power and Sample Size application (PSS) method was used for calculation, and 8 subjects in each group were finally selected as the minimum suitable number.

Inclusion Criteria: 1. Mildly mentally disabled students as the subject group. 2. Subjects were able to participate in sports. 3. Subjects had basic understanding and communication skills.

Exclusion Criteria: 1. Subjects could not participate in normal sports activities due to physical disabilities or illnesses. 2. Subjects had aggressive behaviors in daily activities. 3. Subjects had difficulties in communicating with the teachers.

2.2 Exercise intervention program

The content of this experiment is divided into the badminton group intervention program and the badminton Rong Zhi group intervention program; the intervention content of the two groups is

the same; the preparation part is through the traditional warm-up activities so that the students can be fully warmed up, to prevent the emergence of sports injuries. The end part was based on finishing and relaxation, and the content was the same. Physical fitness exercises were the same in both groups and were carried out utilizing small games or competitions; according to the developmental characteristics of the individual qualities, speed, agility, coordination, and balance qualities were practiced in the first half of the lesson, and strength, endurance, and flexibility qualities were practiced in the second half of the lesson. Based on the intervention period selected by a large number of previous studies and the semester period of the normal population in this age group, we chose a 12-week (3-month) intervention duration in this study.

The difference in the intervention content was in the basic part, where the badminton integration group incorporated cognitive interventions, such as auditory ability, visual ability, conceptual learning, and imitation ability, on top of badminton technical exercises to improve cognitive abilities.

The details of the weekly training components of the sports intervention program are shown in Table 1, while the details of the "plus wisdom" program for cognitive skills are shown in Table 2.

2.3 Cognitive ability test program

This cognitive ability test for students with intellectual disabilities uses the Harbin City Special Education School Students' Personal Growth Test Platform, using the system's visual, auditory, imitation, object constancy, and conceptual learning indicators for this test.

The test was divided into a pre-test and a post-test; in the preparation phase of the assessment test, the assessment selected a quiet and closed classroom, the assessor logged into the system, and the items needed for the test were prepared to ensure that the content of the test subjects can understand and comply with the test requirements. After starting the test, the tester operates according to the content of the test and uses the scoring criteria under its relevant content as the basis for the subject's score, making a good record of the score. The main contents of the test are attention, memory, imitation, object constancy, and concept learning, as shown in Figure 1.

For example, to illustrate the specific operation of action imitation, the evaluator first asks if children are not familiar with a single body language, such as "two fingers aligned with each other and then fingers crossed" for children to imitate. If the child is unable to complete the task, the assessor then gives the child a familiar single-body movement, such as the "two fingers crossed" movement, for the child to imitate. (Note: If the child is asked to look at a familiar movement and cannot perform it, the child cannot be tested again with the same movement; if the child is asked to perform an unfamiliar movement and cannot perform it, the evaluator can still use the same movement to demonstrate it, and the main point of the evaluation is whether or not the child can learn the movement he/she has just performed.) Scoring criteria: 0 points for the subject cannot reproduce (make) familiar single-limb movements, 1 point can reproduce (make) familiar single-limb movements, 2 points can reproduce (make) unfamiliar single limb coherent movements (Garn and Webster, 2018; Liu et al., 2024).

2.4 Data analysis

The collected data were entered into Excel software, and the experimental data were processed and analyzed by SPSS27.0 software. Pre-experimental data were analyzed using one-way ANOVA, with or without differences between the groups in the items tested. Data were collected after the completion of the 12-week intervention experiment, and data before and after the experiment were analyzed by paired-sample t-tests for each group; incremental comparisons between groups were analyzed by covariance tests. In the statistical analysis, $p < 0.05$ was considered a significant difference, and $p < 0.01$ was considered a highly significant difference.

3 Results

3.1 Pre-intervention cognitive ability test results for students with intellectual disabilities

Table 3 compares cognitive ability outcome data of the badminton physical intelligence group, badminton group, and control group before intervention. The dimensions of visual, auditory, imitation, conceptual, and object constancy were tested through the cognitive ability testing platform in special education schools. Using one-way ANOVA, it was concluded that there was no significant difference between the cognitive ability indicators of the pre-intervention groups ($p \geq 0.05$).

3.2 Results of basic motor skills test for students with intellectual disabilities before intervention

Table 4 shows the results of basic motor skill data testing in the pre-intervention badminton physical intelligence group, badminton group, and control group. The motor skill test used the TGMD-2 scale, and the test items included displacement movement (running, front slide, one-legged jump, front straddle jump, standing long jump, and side slide) and object control (*in situ* racket, hitting a stationary ball, catching a ball with both hands, kicking a ball, overhand throwing, and ground ball). A one-way analysis of variance (ANOVA) yielded no significant differences in the basic motor skill indicators among the three groups before the intervention ($p \geq 0.05$).

3.3 Post-intervention cognitive test results for students with intellectual disabilities

3.3.1 Visual ability test results

Comparison of the results of BSI, BS, and CON in the test of cognitive ability in visual ability before and after the intervention, the test of visual ability includes visual attention and visual memory, the data before and after the intervention were analyzed by paired samples t-test, and the results showed that: (1) in visual attention: there was no significant difference in the data of CON before and after the intervention; BSI had a very significant difference in the comparison between the situation before and after the intervention;

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TABLE 1 Details of the content of badminton teaching.

Time	BS group	BSI group
Week 1	① Handicap	① Forward hand ball + auditory attention/visual attention/movement imitation
	② Handicap between rows	② Marching forehand + concrete concept learning/auditory attention/object eternity
	③ Inter-march forehand and backhand	③ Marching forehand and backhand turnover + abstract concept learning/auditory attention/visual attention/verbal imitation
Week 2	①Forehand shot	①Forehand turnover+motion imitation/visual attention/visual memory/object permanence
	②Forward and backhand turnover in the line of scrimmage	② inter-march forehand and backhand turnover + abstract concept learning/auditory attention/visual attention/language Imitation
Week 3	①Review ballistic exercises	①Ballistic exercises + visual attention/auditory attention/verbal imitation/visual memory/auditory memory/abstract concept learning
Week 4	①Backhand serve	①Backhand serve + movement imitation/visual attention/visual memory/object permanence/abstract concept learning
	②Backhand serve at the net	② Backhand serve at the net + visual attention/concrete concept learning/verbal imitation
Week 5	①Sphericality exercise	①Sphericality + concrete concept learning/movement imitation/language imitation/object eternity/abstract concept learning
	②Forehand high ball	②Forehand serve + movement imitation/visual attention/visual memory/object permanence/abstract concept learning
	③Backhand serve at the net	③Backhand serve over the net + visual attention/concrete concept learning/verbal imitation
Week 6	①Cross-step exercise	①Cross-step exercise + visual memory/auditory memory
	②Cross-step exercises	②Cross-step exercise + concrete concept learning/abstract concept learning
	③Stepping exercise	③Stomping exercises + object eternity/abstract concept learning
Week 7	①Forehand serve	①Forehand serve + verbal imitation/visual attention/object eternity
	②Pad exercise	②Pad exercise + movement imitation/concrete concept learning
	③Steps and turns	③Stomping and turning exercises + auditory memory/visual memory
	④Step combination exercise	④Pace combination exercises + movement imitation/auditory attention
Week 8	①Ballistic exercise	①Ballistic exercises + abstract concept learning/object constancy
	②Serve exercise	② Serving practice + verbal imitation/movement imitation
Week 9	①Forehand shot	①Forehand shot+motion imitation/visual memory/concrete concept learning
	②Backhand pick	②Forehand pick + visual attention/abstract concept learning/object eternity
Week 10	①Forehand shot	①Forehand shot + object eternity/abstract concept learning/visual memory
	②Handicap	②Backhand pick + visual attention/visual memory/movement imitation
	③Hand hook	③Forehand hook + verbal imitation/auditory memory/auditory memory
Week 11	①Ball practice	①Ball Practice + visual attention/auditory attention/verbal imitation/
	②Hitting practice	② batting practice + concrete concept learning/abstract concept learning/object eternity
	③Pair batting practice	③Double batting practice + verbal imitation/movement imitation/visual attention
Week 12	①Pace + strike combination exercise	①Pace + striking combination drill + auditory memory/concrete concept learning/visual attention
	②Hitting practice	② Hitting practice +/object eternal/auditory attention/auditory memory/concrete concept learning/abstract concept learning
	③1 V1 match	

BS had a significant difference. (2) In terms of visual memory, the BSI has a very significant difference, the BS has a significant difference, and the CON has no significant difference, as shown in Table 5.

As shown in Table 6, for comparing the incremental visual ability of BSI, BS, and CON before and after the intervention, the incremental changes among the groups were analyzed by analysis of covariance. (2) Visual attention: there was a significant difference in incremental change between BSI and BS; the mean value of incremental change in CON was lower than that of BSI and was significantly different; there was also a significant difference in incremental change between BS and CON. (3) Visual memory: the incremental mean changes of BSI and BS, respectively, compared to CON, were significantly different; BSI compared to BS was not significantly different.

TABLE 2 Details of the content of the "PlusSmart" cognitive training program.

Exercise content	Cognitive intervention	Plus intellectual methods
Invert the ball	Visual attention	Balloons were used as a substitute for the pre-badminton practice, and during the badminton bobble, the teacher held three colored badminton balls and passed by the practicing students and asked for the number or colors they had seen.
Picking up the ball	Visual memory	Pickleball practice with a string attached to a badminton ball to hold the strike position in place. The Rongji group had students look at the model in the teacher's hand before they practiced picking the ball, and after some time, they were asked to point out the model they had seen before.
Pace combination exercise	Auditory memory	Positions on the field where the pace needs to be changed are marked with markers, and students change their pace according to the markers. The Rongzhi group builds on this foundation by using the "speaker" to play animal sounds, with the teacher controlling the "play-pause" and asking each student what kind of animal they heard during the exercise.
Forehand shot	Auditory attention	Practice hitting a tennis ball suspended in the air. The Unity group uses "speakers" to play music so that when the students hear an accent in the music, they start hitting the ball and stop when they hear the teacher's whistle.
Pumping	Motor Imitation	Throw the ball up and when it falls to the marked position, perform a draw against the wall. The Rongzhi group builds on this by imitating a simple movement from the teacher before holding the racket and hitting the ball.
Forehand serve	Verbal imitation	Fix the badminton ball at the striking point, students set up the striking position and practice striking the ball. On top of this, the Unity group imitates and repeats the statements or words spoken by the teacher.
Pace + stroke exercise	Object permanence	Following the teacher's route, run to the marked position, then the supporting teacher throws the ball and the students hit the ball over the net. The Unity Group requires the teacher to ask the students "whether the size of the badminton in the distance is the same as the one in front of them" or "whether there is any change" after the students hit the ball over the net.
Dribbling with racket	Concrete concept learning	The teacher asks the students to place the ball on the racket and run quickly to carry the ball to the finish line. The Rongzhi group requires the teacher to hold red and green markers in a "traffic light," holding up the green as the students run quickly and stop immediately when the red is held up. Badminton dropped students, will pick up the ball placed on the racket surface. Until the end.
Backhand serve	Abstract concept learning	The ball carrier places the ball on the front side of the body, with the center of gravity on the supporting leg, and the racket carrier leads the racket to hit the ball. In the Unity group, 2 numbered zones are marked on the court and students are asked to serve the ball to the "maximum" or "minimum" zone.

3.3.2 Auditory ability test results

Comparison of the results of BSI, BS, and CON in the cognitive ability test of auditory ability before and after the intervention. The auditory ability test includes auditory attention and auditory memory, and the data of the test before and after the intervention were analyzed through the paired samples t-test, and the results showed that: (1) In terms of auditory attention, the mean value of the pre-intervention of the BSI was smaller than the post-intervention, with a very significant difference; and there was no significant difference between the BS and the CON. (2) Regarding auditory memory, the pre-intervention mean of BSI was smaller than the post-intervention, with a highly significant difference; there was no significant difference between BS and CON, as shown in Table 7.

As shown in Table 8, for the comparison of incremental changes in the auditory ability of BSI, BS, and CON before and after the intervention, the incremental changes among groups were analyzed by analysis of covariance, which showed that (1) the incremental changes of the three groups were significantly different in terms of auditory attention; and very significantly different in terms of auditory memory. (2) Auditory attention: the mean incremental value of BSI compared with BS was greater than that of CON, which was a significant difference; for other inter-group comparisons, there was no significant difference. (3) Auditory memory: the incremental means of BS and CON were lower than that of BSI compared to BSI, respectively, both of which were significantly different; there was a significant difference in the incremental value of BS compared to CON.

3.3.3 Imitation ability test results

Comparison of the results of the test of imitation ability in cognitive intervention before and after the intervention of BSI, BS, and CON. Imitation ability includes action imitation and verbal imitation, and the data tested before and after the intervention were analyzed by the paired samples *t*-test; CON, on the other hand, had no significant difference. (2) In verbal imitation, the pre-intervention mean of BSI was smaller than the post-intervention, with a highly significant difference; BS and CON had no significant difference, as shown in Table 9.

As shown in Table 10, for the comparison of the increment of imitation ability of BSI, BS, and CON before and after the intervention, the increment was analyzed by analysis of covariance (ANCOVA) between the groups, and the results showed that (1) BSI, BS, and CON had a highly significant difference in action imitation; and in verbal imitation, BSI had a highly significant difference. (2) Action imitation: the incremental mean values of BSI and BS were higher than that of CON, respectively, and were significantly different; BSI was not significantly different from CON. (3) Verbal imitation: the incremental

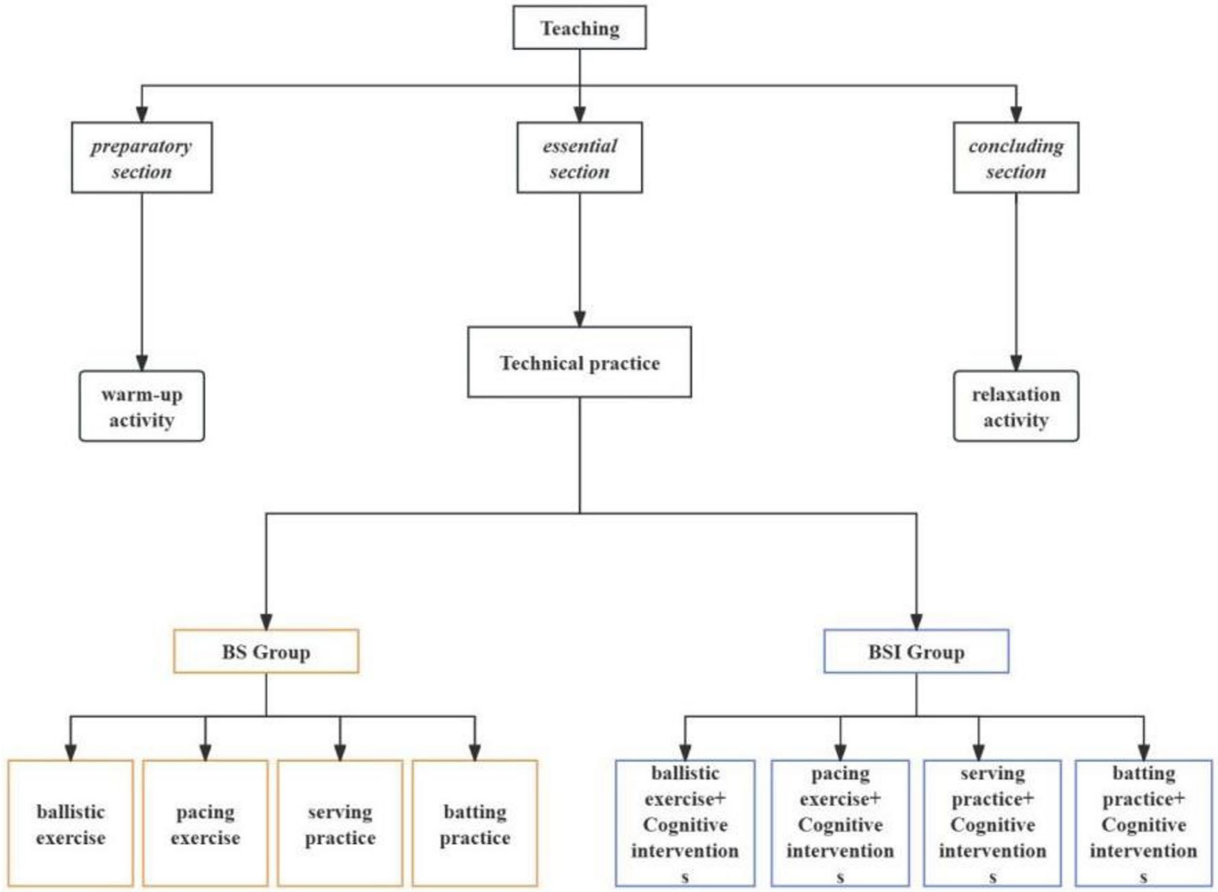

FIGURE 1
Experimental design and implementation process of this study.

TABLE 3 Comparison of cognitive abilities between groups before the intervention.

Test items	BSI	BS	CON	*F*	*P*
Visual attention	5.33 ± 1.50	5.13 ± 1.64	6.11 ± 2.26	0.695	0.509
Auditory attention	2.44 ± 0.88	3.00 ± 1.07	2.22 ± 1.92	0.705	0.504
Visual memory	5.44 ± 2.55	6.25 ± 2.43	6.44 ± 3.21	0.328	0.724
Auditory memory	4.00 ± 2.00	4.00 ± 1.20	5.77 ± 2.49	2.336	0.119
Motor imitation	4.00 ± 1.00	4.37 ± 1.30	5.00 ± 1.12	1.766	0.194
Verbal imitation	2.11 ± 1.36	2.50 ± 0.76	2.67 ± 1.58	0.431	0.655
Object constancy	4.0 ± 1.22	4.13 ± 1.55	4.55 ± 1.51	0.371	0.694
Concrete concepts	9.55 ± 2.70	9.50 ± 3.16	10.44 ± 5.20	0.165	0.849
Abstract concepts	6.33 ± 2.74	8.63 ± 2.50	8.22 ± 3.63	1.434	0.259

*Indicates a significant difference at $p < 0.05$.

means of BS and CON were lower than those of BSI and were significantly different; the incremental changes between BS and CON, on the other hand, were not significantly different.

3.3.4 Conceptual learning ability test results

Comparison of the test results of conceptual learning ability of BSI, BS, and CON in cognitive intervention before and after the intervention. Conceptual learning ability includes concrete and abstract concepts, and the data tested before and after the intervention were analyzed by paired samples *t*-test, and the results showed that (1) in terms of concrete concepts, the mean value of the BSI pre-intervention measurements was smaller than that after the intervention, and there was a very significant difference, and there was no statistically significant difference in the data measured by the BS and CON Before and after the measured data, there was no statistical difference. (2) In terms of abstract concepts, there was a non-significant

TABLE 4 Comparison of motor skills between groups before the intervention.

Test items	BSI	BS	CON	*F*	*P*
Run	2.44 ± 1.67	2.25 ± 1.39	1.89 ± 2.32	0.209	0.813
Forward sliding step	3.11 ± 1.36	1.88 ± 0.99	3.22 ± 2.54	1.458	0.253
Single-legged jump	3.78 ± 1.86	3.88 ± 2.03	2.44 ± 2.13	1.394	0.268
Front straddle jump	1.56 ± 1.13	2.00 ± 0.76	0.78 ± 1.39	2.537	0.101
Standing long jump	2.33 ± 1.58	2.50 ± 1.51	2.00 ± 1.12	0.279	0.759
Side slide	3.78 ± 1.92	2.50 ± 0.76	3.75 ± 1.39	1.535	0.237
Fixed ball	2.44 ± 1.13	2.50 ± 1.07	1.67 ± 1.12	1.555	0.233
Slap the ball in place	3.11 ± 1.05	3.63 ± 0.74	3.78 ± 1.64	0.731	0.492
Catch with both hands	2.67 ± 1.32	2.63 ± 1.06	2.89 ± 1.17	0.123	0.885
Kick	3.33 ± 1.22	3.38 ± 0.74	2.44 ± 2.13	1.074	0.358
Overhand throw	2.33 ± 1.00	2.50 ± 0.93	3.11 ± 2.62	0.500	0.613
Ground ball	2.00 ± 0.87	1.50 ± 0.53	2.33 ± 2.00	0.851	0.440
Total points	32.89 ± 11.22	32.38 ± 9.44	31.67 ± 12.52	0.027	0.973

*Indicates a significant difference at $P < 0.05$.

TABLE 5 Comparison of visual ability between groups before and after intervention.

Test items	Group	Pre-intervention	Post-intervention	Mean difference	*T*	*P*
Visual attention	BSI	5.33 ± 1.50	7.11 ± 1.05	1.78	−4.438	0.002**
	BS	5.13 ± 1.64	6.12 ± 0.83	1.00	−4.320	0.043*
	CON	6.11 ± 2.26	6.00 ± 1.80	0.22	−0.800	0.447
Visual memory	BSI	5.44 ± 2.55	8.11 ± 1.45	2.00	−6.000	0.000**
	BS	6.25 ± 2.43	7.50 ± 1.69	1.25	−2.376	0.049*
	CON	6.44 ± 3.21	5.89 ± 3.44	−0.56	1.474	0.179

*Indicates $P < 0.05$, a significant difference; ** indicates $P < 0.01$, a highly significant difference.

TABLE 6 Comparison of incremental visual ability between groups before and after intervention.

Test items	BSI	BS	CON	*F*	*P*
Visual attention	1.78 ± 1.20a	1.00 ± 1.31b	0.22 ± 0.83c	7.905	0.003**
Visual memory	2.00 ± 1.00a	1.25 ± 1.49a	−0.56 ± 1.13b	15.234	0.000**

Data labeled with the same letter mark or no letter mark represent no significant difference in data between groups ($P \geq 0.05$); those labeled with different letter marks represent significant differences between groups ($p < 0.05$); * indicates $p < 0.05$ and ** indicates $p < 0.01$.

TABLE 7 Comparison of auditory ability between groups before and after intervention.

Test items	Group	Pre-intervention	Post-intervention	Mean difference	*T*	*P*
Auditory attention	BSI	2.44 ± 0.88	4.00 ± 1.32	1.55	−4.603	0.002**
	BS	3.00 ± 1.07	3.25 ± 1.03	0.25	−1.000	0.351
	CON	2.22 ± 1.92	2.33 ± 1.94	0.11	−0.263	0.799
Auditory memory	BSI	4.00 ± 2.00	5.55 ± 2.60	1.55	−5.292	0.001**
	BS	4.00 ± 1.20	4.38 ± 1.06	0.38	−2.049	0.080
	CON	5.77 ± 2.49	6.22 ± 1.68	0.44	−1.512	0.169

*Indicates $P < 0.05$, a significant difference; ** indicates $P < 0.01$, a highly significant difference.

difference in BSI; there was no statistically significant difference in BS and CON, as shown in Table 11.

As shown in Table 12, for the comparison of incremental concept learning ability of BSI, BS, and CON before and after the intervention, the incremental increase among the groups was analyzed by analysis of covariance, and the results showed that (1) the three groups had a highly significant difference in terms of concrete concepts and abstract concepts. (2) Concrete concepts: BSI incremental mean is higher than

TABLE 8 Comparison of incremental auditory ability between groups before and after intervention.

Test items	BSI	BS	CON	*F*	*P*
Auditory attention	1.55 ± 1.01a	0.25 ± 0.71b	0.11 ± 1.27b	5.312	0.013*
Auditory memory	1.55 ± 0.88a	0.38 ± 0.52b	0.44 ± 0.88b	6.557	0.006**

Data labeled with the same letter mark or no letter mark represent no significant difference in data between groups ($P \geq 0.05$); those labeled with different letter marks represent significant differences between groups ($p < 0.05$); * indicates $p < 0.05$ and ** indicates $p < 0.01$.

TABLE 9 Comparison of imitation ability between groups before and after intervention.

Test items	Group	Pre-intervention	Post-intervention	Mean difference	*T*	*P*
Action figure	BSI	4.00 ± 1.00	5.55 ± 0.53	1.55	−6.424	0.001**
	BS	4.37 ± 1.30	5.50 ± 0.53	0.88	−2.966	0.021*
	CON	5.00 ± 1.12	4.77 ± 1.09	0.22	0.800	0.447
Language imitation	BSI	2.11 ± 1.36	3.33 ± 0.83	1.22	−4.400	0.002**
	BS	2.50 ± 0.76	2.75 ± 0.89	0.25	−1.528	0.170
	CON	2.67 ± 1.58	3.11 ± 1.27	0.44	−1.315	0.225

*Indicates $P < 0.05$, a significant difference; ** indicates $P < 0.01$, a highly significant difference.

TABLE 10 Comparison of incremental imitation ability between groups before and after intervention.

Test items	BSI	BS	CON	*F*	*P*
Action figure	1.55 ± 0.73a	0.88 ± 0.83a	0.22 ± 0.83b	8.154	0.002**
Language imitation	1.22 ± 0.83a	0.25 ± 0.46b	0.44 ± 1.01b	7.774	0.004**

Data labeled with the same letter mark or no letter mark represent no significant difference in data between groups ($P \geq 0.05$); those labeled with different letter marks represent significant differences between groups ($p < 0.05$); * indicates $p < 0.05$ and ** indicates $p < 0.01$.

TABLE 11 Comparison of learning ability between groups before and after intervention.

Test items	Group	Pre-intervention	Post-intervention	Mean difference	*T*	*P*
Specific concepts	BSI	9.55 ± 2.70	11.66 ± 4.06	2.11	−3.591	0.007*
	BS	9.50 ± 3.16	9.87 ± 3.18	0.38	−1.426	0.197
	CON	10.44 ± 5.20	10.00 ± 5.15	−0.44	0.883	0.403
Abstract concepts	BSI	6.33 ± 2.74	9.11 ± 3.89	2.78	−5.330	0.000**
	BS	8.63 ± 2.50	9.00 ± 2.14	0.38	−2.049	0.080
	CON	8.22 ± 3.63	7.67 ± 3.74	−0.55	1.048	0.325

*Indicates $P < 0.05$, a significant difference; **indicates $P < 0.01$, a highly significant difference.

TABLE 12 Comparison of incremental learning ability between groups before and after intervention.

Test items	BSI	BS	CON	*F*	*P*
Specific concepts	1.55 ± 0.73a	0.88 ± 0.83a	0.22 ± 0.83b	8.154	0.002**
Abstract concepts	1.22 ± 0.83a	0.25 ± 0.46b	0.44 ± 1.01b	7.774	0.004**

Data labeled with the same letter mark or no letter mark represent no significant difference in data between groups ($P \geq 0.05$); those labeled with different letter marks represent significant differences between groups ($p < 0.05$); * indicates $p < 0.05$ and ** indicates $p < 0.01$.

CON, which is a significant difference; CON compared to BS in terms of the change of incremental mean is not a significant difference. (3) Abstract concepts: BSI incremental mean change is higher than BS and CON and is significantly different; BS is not significantly different compared to CON.

3.3.5 Object constancy test results

Comparison of the results of the BSI, BS, and CON in the object constancy test in the cognitive intervention before and after the intervention The data tested before and after the intervention were analyzed using a paired samples t-test, which showed that the data analyzed as measured by the BSI were significantly different, whereas there was no significant difference between the BS and the CON, as shown in Table 13.

4 Discussion

The cognitive ability of students with intellectual disabilities is an important indicator of intelligence, as their own deficiencies cause

TABLE 13 Comparison of object constancy in each group before and after the intervention.

Test items	Group	Pre-intervention	Post-intervention	Mean difference	*T*	*P*
Object constancy	BSI	4.00 ± 1.2	5.33 ± 0.7	1.33	−5.657	0.001**
	BS	4.13 ± 1.55	4.50 ± 0.93	0.38	−1.426	0.197
	CON	4.55 ± 1.51	4.33 ± 1.73	−0.22	0.286	0.782

*Indicates $P < 0.05$, a significant difference; ** indicates $P < 0.01$, a highly significant difference.

them to lag behind normal students in cognitive level, which has a serious impact on their intelligence (Alnahdi, 2019). Therefore, many experts and scholars have used various interventions to improve the cognitive abilities of people with intellectual disabilities and to help them participate in social life in the future (Hollis et al., 2017; Frances et al., 2022). Previous studies have concluded and proved that sports could improve the cognitive level of the intellectually disabled group, but it is especially necessary to pay attention to the choice of sports and the operation process of teaching skills; simple and mechanical forms of sports activities are not necessarily able to get higher acceptance of the training object, such as running, resistance training, etc. (Ginis et al., 2021). Therefore, some scholars believe that individual small ball sports activities that are rich in fun seem to be more easily accepted by this kind of children's locks (Chang, 2021).

The deficits in attentional functioning that exist in the mentally handicapped group become one of the obstacles that affect their normal life (Crespi et al., 2010; Shogren et al., 2014). Therefore. The attentional function in this study is mainly tested in terms of visual attention (van der Aa et al., 2023) and auditory attention (Kim et al., 2021) dimensions. Visual attention is a subsystem in the attention system under neuropsychological mechanisms and is one of the research directions in the field of contemporary cognitive psychology and neuroscience (Lu et al., 2023). Auditory attention refers to the stimulation of external sound signals by a person, which causes the neural mechanisms of the brain to make processing (Obleser and Kayser, 2019). Numerous studies have shown that auditory attention reflects the neural development of the brain and plays a crucial role in human cognition (van Ede and Nobre, 2023; Liu et al., 2022). In this study, it was found that there was a significant difference between the pre-and post-intervention means of the physical intelligence group and the badminton group in terms of visual attention ($p < 0.05$); the increment of both groups was higher than that of the control group. Regarding auditory attention, only the physical and intellectual groups had a significant difference ($p < 0.05$). This shows that the teaching intervention program for the badminton physical intelligence group was superior to that of the badminton group. Similar to the previous study, after 8 weeks of badminton practice intervention, it was found that the visual attention level of junior high school students increased significantly in the dimensions of transfer, breadth, stability, and distribution, and it was concluded that the high demands of badminton on visual and auditory attention help stimulate the trainers' brains. The good effect of the "body-intelligence integration" badminton teaching in this study may be because the varied forms of badminton and the need to analyze the changes in the field of play stimulate an increase in dopamine in the frontal lobe central receptors, which leads to an improvement in neuronal receptor blunting (Protzner et al., 2015; Abdollahipour et al., 2023).

In previous studies on normal children, it was found that the effects of different sports on visual memory were found to have an effect on the student's visual memory and that visual attention had an interactive effect on the development of visual memory (Maenner et al., 2021; Baio et al., 2018; Liu et al., 2024; Alnahdi, 2019; Abdollahipour et al., 2023; Lind et al., 2019; Benzing et al., 2018; Chan et al., 1893). However, less attention has been paid to special groups; this study found that in visual memory, the BSI and BS groups had a significant effect before and after the experiment; the increment of both groups was higher than that of the control group ($p < 0.05$). In auditory memory, the BSI group had a significant effect on change, and its incremental change was the largest. In badminton, technical movements of the body force, coordination, accuracy, and other requirements must be dominated by the brain of students with intellectually disabled control, cortical nervous system excitation, and inhibition. The sport itself can increase the degree of excitation of the nervous system, and endocrine hormones produced by the movement can also promote the transmission of chemical information in the synapses (Dongmoon and Eun-Sun, 2018). More critically, the integration of intellectual training into badminton through the exercise increases the excitability of the nervous system integration of memory content interventions suitable for students with intellectually disabled, prompting the formation of new neural networks and increasing the plasticity of synapses, resulting in the improvement of their memory (Ludyga et al., 2022; Ludyga et al., 2016).

As a core mechanism of imitation ability as a unique social cognition, previous studies have suggested that the generation of imitation ability is associated with the associative activation of visual and motor representations in imitative behaviors (Web of Science, 2025a). It has been found that imitative ability can lead to gains in language development and motor skill acquisition in exceptional students through imitative training in receptive language and gesture and can activate the imitator's cortical nerves to speed up the transmission and processing of the received information, resulting in an increase in the functional activity of the mirror nervous system (Hale and Hamilton, 2016). The imitation ability in this study is mainly from two aspects: motor and verbal. In this study, it was found that the BSI group was better than the BS group in terms of improving this ability. Dual-task training combining cognitive and ball games was found to be more effective in improving this ability in this group of children, probably because of the close relationship between the level of activation and activity of the brain's nervous system (Koch et al., 2018). It has been suggested that imitation is associated with extensive activity in the cerebral cortex, resulting in increased bilateral activity in several motor subcortical areas in the cerebellum, central sulcus, and supplementary motor areas (Al-Hashimi et al., 2015; Moisala et al., 2016).

Numerous previous studies have shown that appropriate exercise improves the quality and efficiency of students' learning and has a positive effect on their cognitive abilities. In an intervention on object class concepts for children with intellectual disabilities aimed at

improving their thinking skills, it was thought that it was possible that the addition of exercise along with separate thinking exercises would have better results, and our study confirms this previous conjecture (Web of Science, 2025b; Moore, 2023). The comparison of means before and after the intervention of the BSI had a significant change in effect, while there was no change in effect for the BS and CON. Increments in the BSI compared to the CON and BS groups, respectively, had a significant difference in effect. CON and BS groups were significantly different compared to each other. It is possible that this result is because through exercise, the body secretes physiological hormones that affect the activity of the nervous system, such as norepinephrine (Pietrelli et al., 2018), dopamine (Petrican et al., 2024), and other physiological hormones (Donato and Kopchick, 2023), which can promote the excitation and activity of the cerebral cortical nerves, so that the energy substance is sufficiently used within the brain, and the inter-neural information transmission is accelerated, improving the concentration and agility of thinking (Janssen et al., 2014).

It can be seen from the above analyses that the improvement of cognitive ability by "physical and intellectual" integration of badminton teaching interventions is significantly better than that of badminton teaching interventions. Therefore, the effective combination of physical education and cognitive intervention is conducive to the overall development of students with intellectual disabilities. After this study, it was found that the cognitive intervention program should be reasonably designed according to the characteristics of the sport.

5 Conclusion

This study found that compared with badminton alone, adding cognitive training intervention to badminton can effectively improve the cognitive ability of students with intellectual disabilities in vision, hearing, imitation, concept learning, object constancy and other aspects, and has a better effect on the object control of children in this group, which may be because the interesting nature of badminton itself amplifying the effect of cognitive training. Based on this, in the special education for such children, teachers can consider adding cognitive training to badminton to improve the well-being of special 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/s.

Ethics statement

The studies involving humans were approved by the Harbin Badminton Federation Ethical Review 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

YW: Conceptualization, Data curation, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. DZ: Conceptualization, Data curation, Methodology, Validation, Writing – original draft, Writing – review & editing. CL: Conceptualization, Formal analysis, Validation, Writing – original draft, Writing – review & editing. LL: Project administration, Writing – review & editing. GC: Conceptualization, Methodology, Project administration, Resources, 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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Global research trends on physical education practices: a bibliometric analysis and science-mapping study

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Background: Physical Education teacher training, specifically internships, require the application of theory to real-life contexts. Although these internships are mandatory in training programs, they are often undervalued. This study aims to provide an overview of research in this field and highlight future trends to contribute to the development of strategies for improving teacher training. The study analyzes the training of Physical Education teachers, emphasizing the importance of professional practice in applying theory to real-world contexts.
Methods: To identify trends and improve teacher training, a bibliometric analysis was conducted on 83 publications retrieved from the Social Sciences Citation Index and the Science Citation Index Expanded in Web of Science.
Results: Since 2010, a significant increase in publications on this topic has been observed, mostly in English, with 1,827 citations and an average of 22.01 citations per article. The documents had 198 authors from 27 countries, with the United States being the most prolific. The analysis revealed three research clusters: one focused on "attitudes" and "inclusion" of children with disabilities, another on "Physical Education" and "teachers' beliefs," and a third centered on "practices" and "perception" in adapted Physical Education. International collaboration was variable, with institutions predominantly from the United States, Brazil, and Spain. The most influential journals included Adapted Physical Activity Quarterly and Physical Education and Sport Pedagogy.
Conclusions: The study reveals a notable growth in research on Physical Education practicums since 2010, with three main thematic clusters and a low level of author collaboration.

KEYWORDS

physical education, practicum, bibliometrics, productivity, network analysis, web of science

1 Introduction

Currently, the need for highly trained teachers is increasingly evident (1). Research on teacher training over the past decade has highlighted the complexities and systematic nature of this process, emphasizing the crucial role of key inputs, such as material resources, curriculum, faculty, and infrastructure, along with the learning environment in shaping the outcomes of future professionals (2). However, this process faces considerable challenges, including a shortage of trained personnel, outdated training programs, high costs, and the need for effective evaluation of training quality and impact (3–5).

In this context, professional internships play a fundamental role in the development of undergraduate and postgraduate students. Practical experience is essential in shaping the identity and skill set of future professionals (6, 7). This process involves multiple factors—such as the curriculum, student interns, teacher educators, and the environment—who collectively influence the quality of graduates (2, 8).

These internships allow for acquired knowledge to be applied in a real and supervised environment (9). Additionally, they help students gradually transition into professional life by providing networking opportunities, the development of interpersonal skills, employment prospects, and engagement in meaningful tasks (7, 10). Therefore, internships are considered a type of field-based learning experience and are valued by teachers, students, and educational institutions seeking to hire future professionals. These experiences can considerably influence the career trajectories of pre-service teachers (11).

In this context, experiential learning is an educational approach that emphasizes learning through direct experience, which can be important for professional development and the acquisition of future professional competencies (12). A recent meta-analysis conducted by Burch et al. (13) on experiential learning concluded that students who applied it experienced superior learning outcomes.

Within Sports Sciences, specifically Physical Education, knowledge can be applied effectively inside and outside the classroom (14). Therefore, internships have become an essential component of professional Physical Education preparation programs across various countries (2, 15–19). However, higher education has not always adequately valued practical experience, instead traditionally prioritizing academic content over practical subjects (20, 21).

Recognizing that the literature offers multiple definitions of practicums, we define them as crucial spaces for connecting academic theory with future work environments (22, 23). This period is fundamental for university students (24, 25), as it allows them to explore the internal processes of their professional development and thus fosters their identity construction (25–27). As highlighted by Lizana (25) and Mañas-Olmo (28), this topic has garnered increasing interest in the scientific community in recent years.

In this context, it is necessary to thoroughly review all available information on the research on educational and training practices in Physical Education (17). Given the volume of resources invested in this research, it is crucial to have tools that quantify their results and impact. In this respect, bibliometrics has established itself as a fundamental tool in research evaluation (29).

Bibliometrics, as a statistical analysis method, plays a key role in identifying research trends and evaluating its impact (30). It enables the analysis of large volumes of scientific literature and guides decision-making in the development of new projects (31, 32). Moreover, it facilitates the study of author cooperation, citations, journals, and institutions and thereby contributes to the visibility of research and the assessment of its reach and influence (33).

Bibliometric analyses reveal the most productive authors, collaborations among them, the most active research centers, and how the work is disseminated at national and international levels (34, 35). Understanding these dynamics helps consolidate collaborative networks, foster the exchange of ideas, and expand scientific discussions on practices in Physical Education (29, 36).

Although bibliometric mapping in educational practices has been widely studied in recent years (28, 17, 37–39), to date, no bibliometric studies have been conducted specifically on Physical Education practicums. Exploring the field's current state and future perspectives allows for a better understanding of the knowledge structure and development in the educational domain, providing new strategies for teacher training.

Therefore, this study aims to provide an overview of research in this field and to highlight future trends, with the goal of contributing to the development of strategies that improve teacher training.

2 Materials and methods

2.1 Search strategy and eligibility criteria

The raw data were obtained and downloaded from the Web of Science Core Collection (WoSCC), which includes the Science Citation Index Expanded (SCIE) and the Social Sciences Citation Index (SSCI), developed by Clarivate Analytics of Thomson Scientific. WoS hosts a vast number of high-quality, impactful scientific studies, and it is the most comprehensive and exhaustive collection of information available worldwide (33, 40). Because citation data vary by database, WoS is considered the best option for bibliometric studies (40, 41).

The search strategy employed the terms ("practicum" OR "practice") AND ("Physical Education"), which allowed for the retrieval of all articles and reviews related to specific practices in the field of Physical Education published online between 1900 and 2024 in the WoSCC, including SCIE and SSCI.

To reduce the risk of bias, two authors independently retrieved the documents on May 1, 2024, between 6:00 PM and 9:00 PM. Afterward, the documents that met the inclusion and exclusion criteria were selected and exported. The inclusion criteria were a document type of article or review; the exclusion criteria were a document type of proceeding paper or editorial material and anomalous document. The detailed search and selection process is illustrated in Figure 1.

Because only articles and reviews were considered, five documents were excluded. Additionally, 35 documents were removed after both authors reviewed them and determined they did not match the terms used in the search strategy. Ultimately, 83 original articles and reviews were included for the in-depth analysis and visualization.

The selected articles were exported to an Excel file, where the following variables were recorded: citation number, journal name, publication year, author and co-author names and surnames, total number of authors, authors' geographical locations and associated institutions, article title, document type (article or review), abstract, and corresponding author. For the authorship analysis, all individuals who contributed to each study were included in the count.

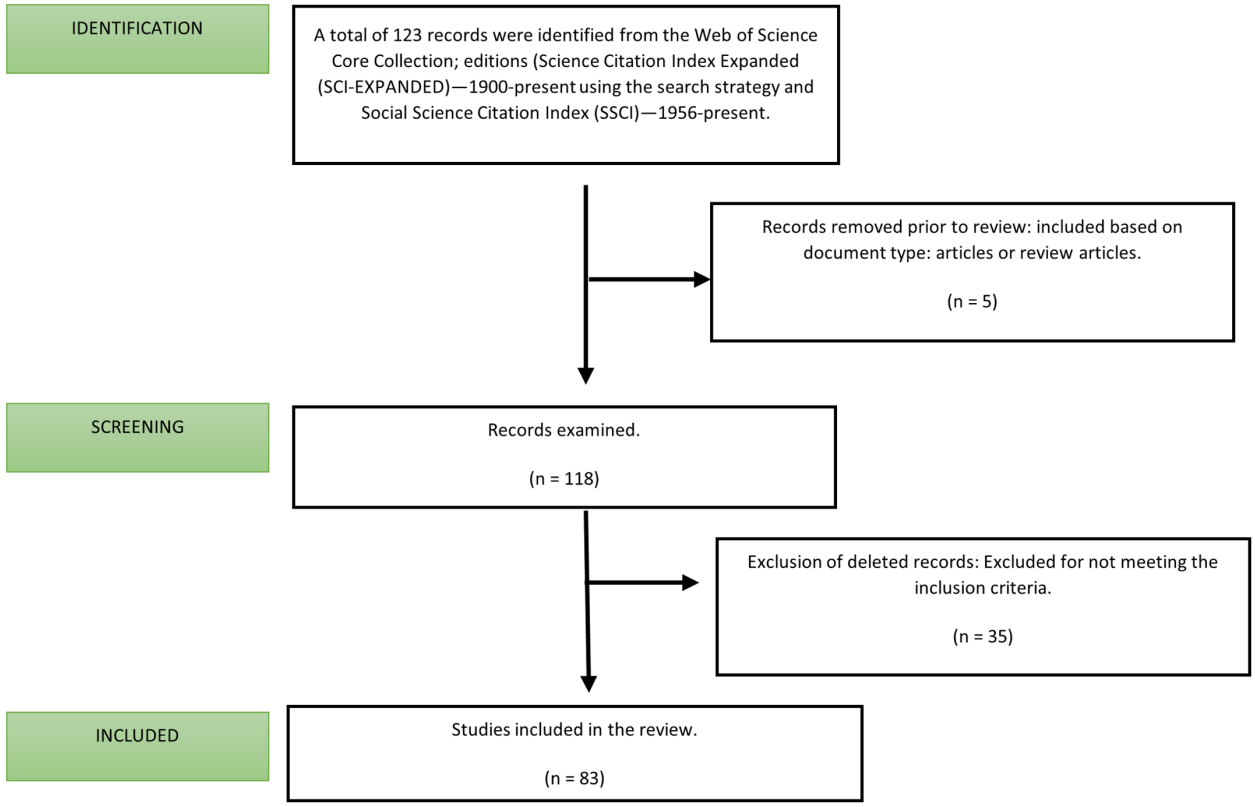

FIGURE 1
Study flowchart.

Regarding the bibliometric analysis by country, following previous studies (29, 32), the country of origin of each author involved in the study was considered as was the number of citations an article received. If a country received multiple citations for the same study, the citations were not counted more than once, even if the authors were from different institutions within that country. The total number of articles per country was determined based on whether at least one author was affiliated with that country.

To calculate each author's citation number and Hirsch index (h index), this study considered only articles and citations related to the study's subject matter.

2.2 Bibliometric analysis

Objective and evaluative bibliometric techniques were employed to visualize and analyze the research on Physical Education practicums. Objective bibliometrics focuses on measuring the literature's quantity and the citation numbers, and it includes a citation analysis (42). The key indicators of productivity, impact, and publication quality are the number of publications (Np), the number of citations (Nc), and the average number of citations per article (Na), respectively.

On the other hand, evaluative bibliometrics provides quantitative assessments of contributions to the research field from various countries, authors, journals, and institutions, and it uses the h index as the main metric (43). This type of analysis helps to identify the most influential articles in the field's evolution, and it detects current research hotspots and future trends (44).

2.3 Statistical analysis

SPSS 27.0 software (IBM, United States) was used for the correlation analysis. Additionally, Microsoft Excel was used to perform a linear regression analysis and assess the publication trend over time. A polynomial model was applied to predict the increase in the number of publications.

To identify cooperation networks and analyze keyword co-occurrence, this study used VOSviewer 1.6.18 (CWTS, Netherlands), a tool widely employed in bibliometric analyses (45). Moreover, the R Bibliometrix package (version 4.2.2) was used because the program is designed to conduct quantitative analyses in scientometrics and informetrics (46). This tool extracts metadata, thus allowing the classification and analysis of the bibliographic data imported from WoS and large volumes of research data over a specific period.

The analysis identified concurrent relationships between the keywords used and their distances on the knowledge map. Map interpretation was enhanced through the use of color, size, and distance rankings (clusters or nodes) of the evaluated keywords.

Furthermore, the software generated visual representations of the knowledge. Finally, MapChart was used to create a customized map.

3 Results

A total of 83 documents were analyzed, of which 80 were articles and 3 were reviews, and the majority of these documents was published in the last decade. The predominant language was English (75 documents), followed by Portuguese (7) and Spanish (1). In total, the publications received 1,827 citations, with an average of 22.01 citations per article. The study involved 198 authors from 27 countries, and the articles were published in 29 journals.

3.1 Global publishing landscape

The analyzed documents were published between 1993 and 2024, with 82% appearing after 2010. Although some fluctuations were observed, the overall trend showed a clear upward trajectory. We performed a publication trend analysis using a fitting curve, which suggested a sustained upward trend in the coming years. A notable increase in the volume of publications was evident, with exponential growth in recent years. Our linear regression analysis revealed a significant, positive correlation between the number of annual publications and the publication year ($R^2 = 0.736$, $p < 0.001$) (see Figure 2). This finding indicates that scholars are paying increasing attention to the research field of Physical Education practicums.

A keyword analysis offers valuable insights into key research topics and emerging trends. This analysis was developed using VOSviewer and included titles, keywords, and abstracts. The network was created from 391 keywords, which were selected for further analysis if they appeared in at least five publications, resulting in 22 keywords selected for network inclusion. The results of this analysis are presented in Figure 3, which shows three distinct nodes.

The first node (red) consisted of eight keywords—including "attitudes," "children," "disabilities," and "inclusion"—and "attitudes" had the greatest number of connections, so the node was thus titled. This keyword shared 18 links with the other keywords on the map and had a total link strength (TLS) of 50. In descending link order were the keywords "inclusion" ($n = 16$; TLS 51), "disability" ($n = 16$; TLS 26), "individuals" ($n = 16$; TLS 39), "disabilities" ($n = 15$; TLS 43), "children" ($n = 15$; TLS 30), "teaching students" ($n = 15$; TLS 36), and "practical experiences" ($n = 13$; TLS 29). The keywords in this node reflected a research focus on practices associated with children with disabilities and attitudes toward their inclusion. This assumption was confirmed by the fact that the highest connection strength was between the keywords "inclusion" and "attitudes."

The second node (green) included eight keywords such as "Physical Education," "beliefs," "curriculum," "student teachers," and "teacher training." This node was named after its most prominent keyword, "Physical Education," which dominated the node by linking to 20 of the other keywords on the map and by having a TLS of 52. In descending link order were the keywords "beliefs" ($n = 16$; TLS 32), "curriculum" ($n = 14$; TLS 20), "student teachers" ($n = 11$; TLS 13), "teacher training" ($n = 10$; TLS 13), "programs" ($n = 10$; TLS 15), and "self-efficacy" ($n = 5$; TLS 8). The keywords in this node reflected a research focus on

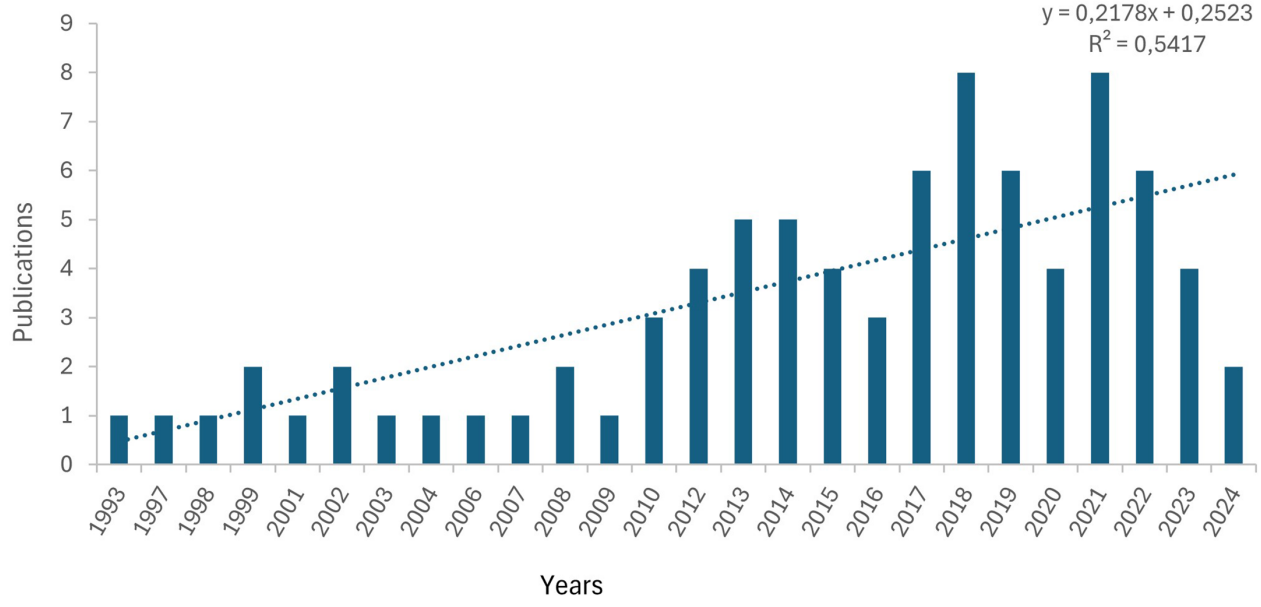

FIGURE 2
Annual article distribution pattern.

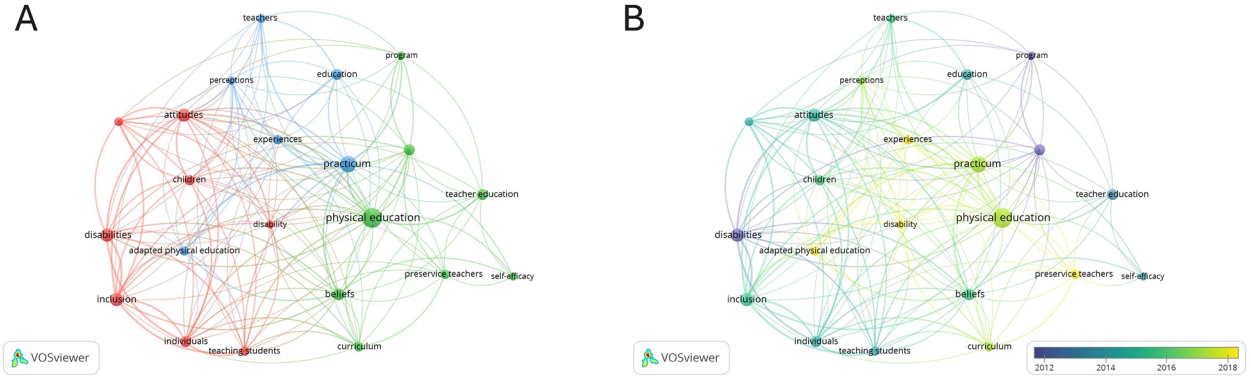

FIGURE 3
(A) keyword co-occurrence network. Node size indicates occurrence frequency. The curves between the nodes represent keyword co-occurrence in the same publication. Shorter node distances indicate higher keyword co-occurrences. (B) Relationship between keywords over time. Keyword colors indicate their average publication period, calculated by taking the average of the publication years of all publications.

the beliefs held by future Physical Education teachers. This conclusion was reinforced by the strong connection between the keywords "Physical Education" and "beliefs."

The third node (blue) included six keywords such as "practices," "education," "perception," "teachers," and "adapted Physical Education." This node was named "practices," the most prominent keyword with the greatest relevance, as it linked to 19 of the node's other keywords and had a TLS of 45. In descending link order were the keywords ($n = 11$; TLS 14), and "experiences" ($n = 10$; TLS 15). The keywords in this node reflected a research focus on practices as well as on teachers' perceptions and experiences regarding adapted Physical Education. This conclusion was reinforced by the strong connection between the keywords "practices" and "perception" (see Figure 3A).

The most frequently used keywords occurred from 2012 to 2018. Older keywords were represented in blue, while more recent ones were shown in yellow. The nodes' color ranges and sizes indicated that the most recurrent keywords emerged from 2016 to 2018. The nodes with more recent keywords were related to "Physical Education," "practices," "adapted Physical Education," and "student teacher." In contrast, the node associated with "disabilities," "programs," "efficacy," and "teacher training" corresponded to older keywords. These findings demonstrate that the most recent research has focused on adapted Physical Education, particularly in its relationship with teaching practices during training periods (Figure 3B).

3.2 Authors and Co-authors

A total of 198 authors contributed to the articles on Physical Education practicums. The number of authors per article ranged from 1 to 6, with an average of 2.95. Our analysis of the 10 most productive authors was based on the number of articles published without considering authorship position, and it revealed that S.R. Hodge, T. Sato, and G. González-Calvo were the most prolific authors in this field.

S.R. Hodge, a professor at the College of Education and Human Ecology at Ohio State University, United States, had the highest citation number (257) with six published articles and an h index of 5 in relation to Physical Education practicums. He averaged 42.83 citations per article. T. Sato—initially affiliated with the Faculty of Health and Sport Sciences at the University of Tsukuba, Japan, and later with Kent State University, School of Teaching, Learning, and Curriculum Studies in Kent, United States—was the second most productive author, with five articles that were cited 93 times for an average of 18.5 citations per article and an h index of 4. Third was G. González-Calvo, from the University of Valladolid, Spain, who published 4 articles and had an h index of 5 and an average of 53.5 citations per article (see Table 1).

Our analysis showed that the total citation number was not related to the number of authors participating in the studies ($rs = -0.092$, $p = 0.008$). Furthermore, the author collaboration network analysis revealed no significant collaboration network. Some of the 27 elements in the network exhibited no connections, and the largest connected group consisted of only four members.

The productivity of the leading authors over time can effectively reflect the temporal distribution and number of

TABLE 1 Top 10 authors in the research on physical education practicums.

Author	Np	H index	First author	Last author	Co-author	Nc
Hodge, S.R.	6	5	4	1	1	257
Sato, T.	5	4	4	0	1	93
González-Calvo, G.	4	5	2	1	1	214
Rossi, T.	4	3	1	3	0	69
Tinning, R.	4	4	0	1	2	104
Haegele, J.A.	4	3	0	3	1	67
Hutzler, Y.	3	3	2	0	1	153
Sirna, K.	3	3	2	0	1	103
Varea, V.	3	3	2	0	1	193

Np, number of publications; Nc, number of citations.

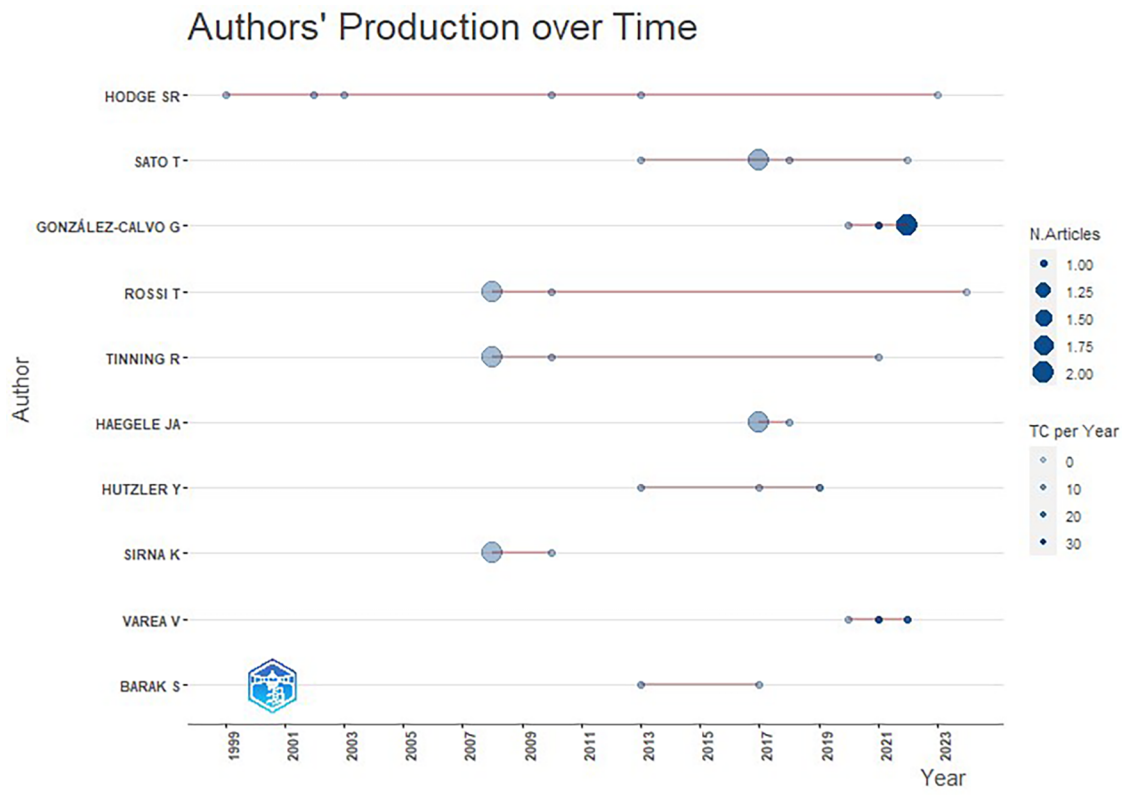

FIGURE 4
Authors' production levels over time on physical education practicums. Circle size indicates the number of documents, and color indicates the number of citations.

articles published during a given period. As shown in Figure 4, S.R. Hodge has been the most productive and consistent author in the research on Physical Education practicums over the past two decades, steadily and annually producing articles and having a high total citation index. In contrast, T. Sato, G. González-Calvo, and T. Rossi have published over the past decade but only in recent years have they achieved excellent performance in terms of output and total citations.

3.3 Countries, institutions, and collaborations

Researchers from 27 countries published 83 articles on the analyzed topic. Table 2 shows the 10 most productive countries. The United States contributed 29 documents; followed by Brazil, who contributed 9; and Australia, Canada, and Spain, who each contributed 8. The countries with the highest citation numbers were the United States, China, Ireland, and Sweden. Regarding the average number of citations per article, Israel led with 48.25; followed by Ireland, with 44; and Sweden, with 35.17.

The publications on Physical Education practicums originated from 27 countries, distributed as follows: 17 in Europe, 4 in Asia, 3 in the Americas, 1 in Africa, and 2 in Oceania. Figure 5 illustrates the global distribution of these publications by country and region.

TABLE 2 Countries with the highest citation numbers in the research on physical education practicums.

Country	Nc	Np	Na	H index
United States	711	29	24.5	17
Brazil	32	9	3.56	3
Australia	142	8	17.75	6
Canada	149	8	18.63	5
Spain	180	8	30	4
People's Republic of China	235	6	29.38	5
Sweden	211	6	35.17	4
Ireland	220	5	44	4
Norway	62	5	12.4	4
Israel	193	4	48.25	4

Np, number of publications; Nc, number of citations; Na, average number of citations per article.

The five most productive countries, which represented only 18.5% of the total, generated nearly 53.4% of the publications. More than half of the countries contributed only one or two documents. A single publication may be linked to multiple countries or institutions because authors can have multiple affiliations at the country and the institution levels. The United States produced the largest number of publications, followed by Brazil, Spain, Canada, and Australia.

Figure 6 shows the publication growth trends in the six most productive countries from 1993 to 2023. Compared with the

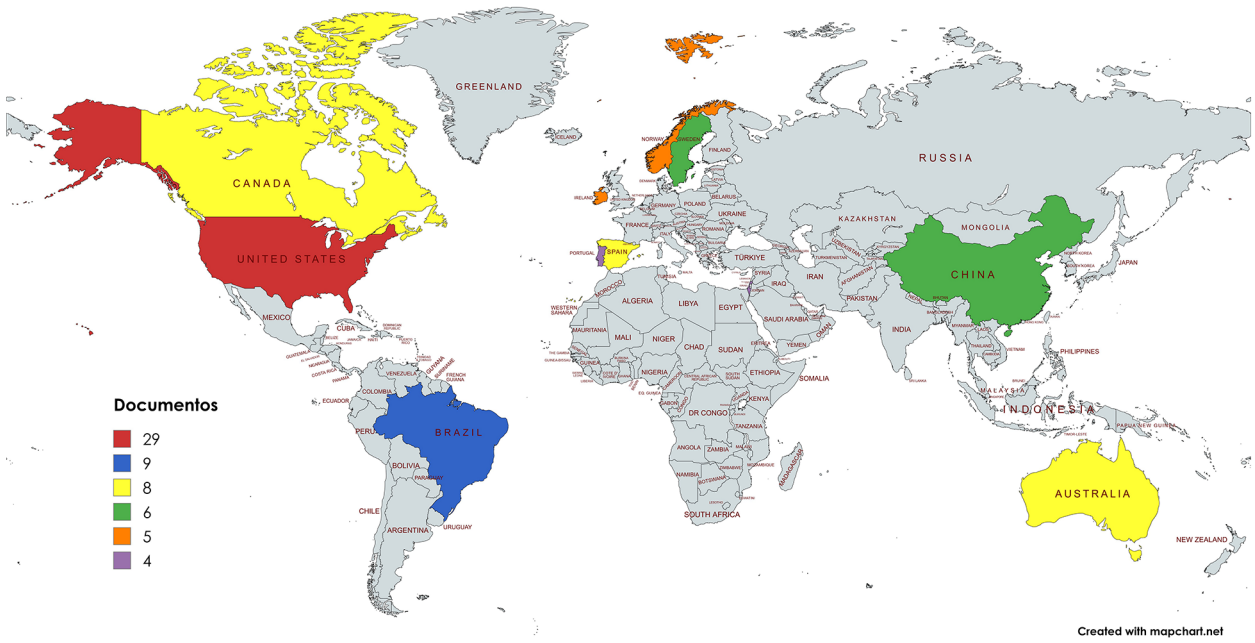

FIGURE 5
Distribution map showing the number of articles published by country (mapChart).

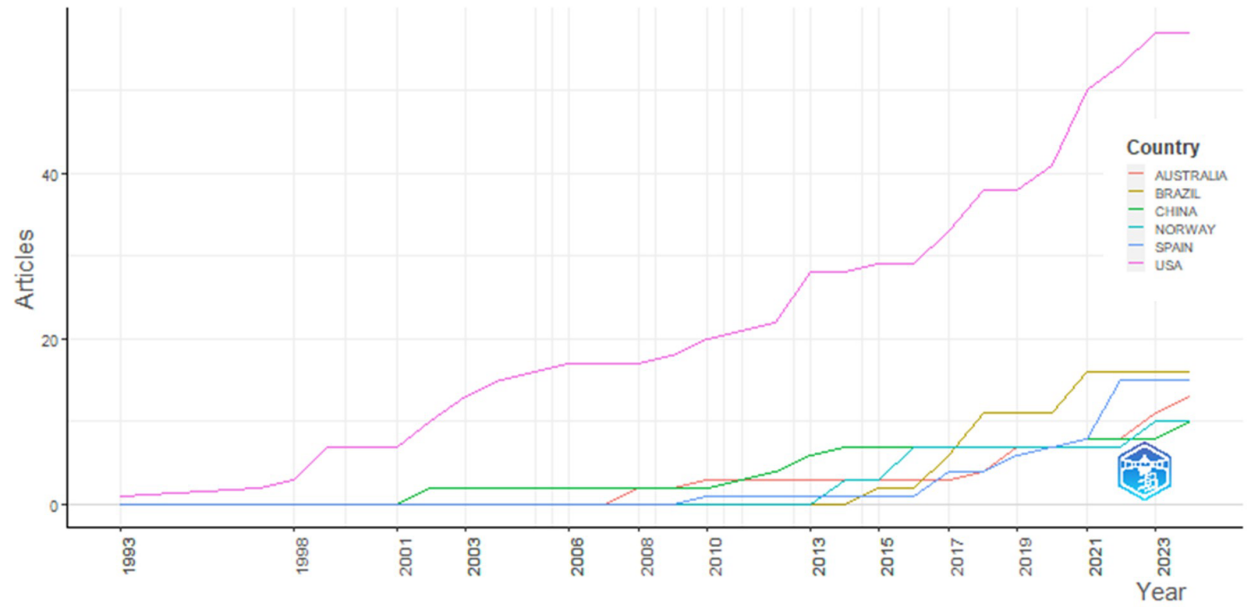

FIGURE 6
Production by country over time.

other five countries, the United States had the most rapidly increasing upward trend in the number of publications since 2001. Since 2007, and especially since 2013, publications in the other five countries have grown steadily, but growth in the United States has been three times higher than it has in the other countries.

Figures 7A,B show our analyses of citations by country and collaboration networks between countries, conducted using VOSviewer software. The network was constructed with data from 27 countries, and the inclusion criteria were at least four collaborative publications. The analyses resulted in four main citation nodes (Figure 7A) and five collaboration nodes (Figure 7B).

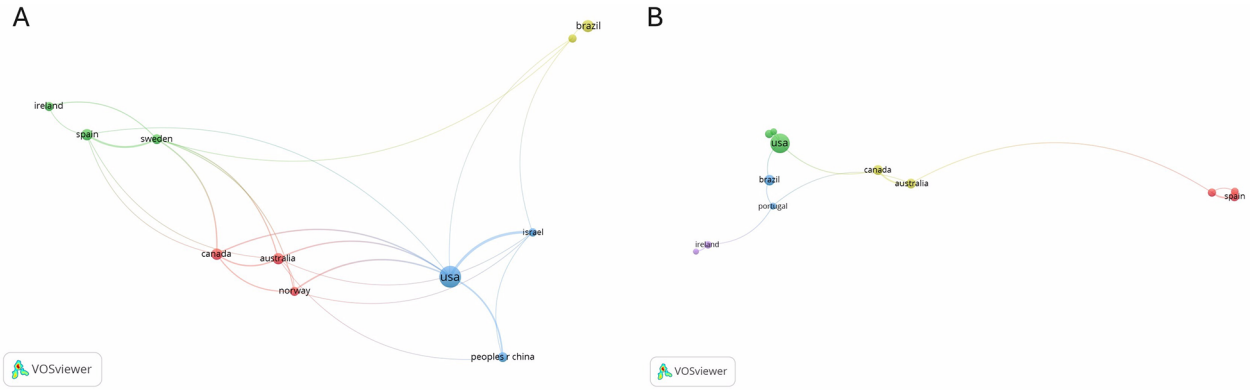

FIGURE 7
(A) citation analysis by country. (B) Collaboration networks between countries.

The first citation node (red) grouped together Australia, Canada, and Norway. In this node, Australia had the most active associations, with eight collaborative documents. In addition to Canada and Norway, its main research partners included the United States, Sweden, Spain, Israel, and China.

The second node (green) was centered on Sweden, Spain, and Ireland, with Sweden in the lead with seven collaborative documents. Sweden's main partners were Portugal, Canada, Australia, and Norway.

The third node (blue) revolved around the United States, which produced 29 collaborative documents. Its main connections included China, Israel, Australia, Spain, Canada, Portugal, and Norway.

The fourth node (yellow) focused on Brazil, which had nine collaborative documents. Brazil's main partner in this network was Portugal.

The citation nodes largely aligned with the collaboration nodes between countries. The only exception was the occurrence of a fifth collaboration node (purple) that included Ireland and Greece.

Figure 8 shows the geographic distribution of collaboration between countries during the overall study period. The analysis was conducted using Bibliometrix software and highlighted the strong level of cooperation between Australia and Canada, which had three documents, and New Zealand, which had two. Similarly, Sweden and Spain demonstrated a strong cooperation trend, with three articles.

3.4 Key journals and articles

The 83 analyzed publications originated from 142 institutions, according to the available affiliation data. A single article may have multiple authors, and an author may be affiliated with more than one institution. The number of institutions per article ranged from 1 to 9, with an average of 2.6.

Of the total institutions, 71.1% ($n = 101$) supported a single publication, 14.8% ($n = 21$) supported two publications, and 12% ($n = 17$) supported 3–5 publications. Only three institutions (2.1%) supported 7–10 publications.

Figure 9 shows the 10 most productive institutions, and the University System of Ohio was the most prolific, with 10 publications. Of these 10 institutions, 5 were located in the United States, while 4 were in Europe (Spain, Norway, Sweden, and Ireland), and 1 was in Australia. Among them, the University of Limerick and Örebro University had the highest average citations per article, with 54.25 and 54.5, respectively.

The relationship between the total citation number and the number of institutions involved in each study revealed a negative correlation, with a coefficient of determination equal to 0, suggesting that these variables were independent (see Table 3).

While most of the participating institutions were universities, the analysis also revealed the involvement of research centers and institutes as well as some private institutions (see Table 3).

The collaboration network analysis (see Figure 10A) was based upon a minimum of two collaborations between institutions. Of the institutions analyzed, 29 exceeded this threshold, forming three cooperation nodes. The first node (red) highlighted collaborations between the University of Wisconsin, Texas Woman's University, and Korea National Sport University, with three shared documents. The second node (green) involved Kent State University and Old Dominion University, with four documents. The third node (blue) illustrated the strong cooperation between Ohio State University and other institutions, with seven shared documents.

For the citation network analysis (see Figure 10B), the same criterion of a minimum of two collaborations was applied to identify five citation nodes among the 29 institutions that met the threshold. The first node, involving seven institutions, was led by the University of Valladolid and Örebro University, with a link strength of 6 and a TLS of 11, sharing five documents. These institutions formed a citation network with Douglas College, the University of Queensland, the University of Limerick, and the University of Auckland.

The second citation node (green) also included seven institutions, with Ohio State University being the most active, with a link strength of 11, a TLS of 40, and seven shared documents. This university collaborated closely with Georgia

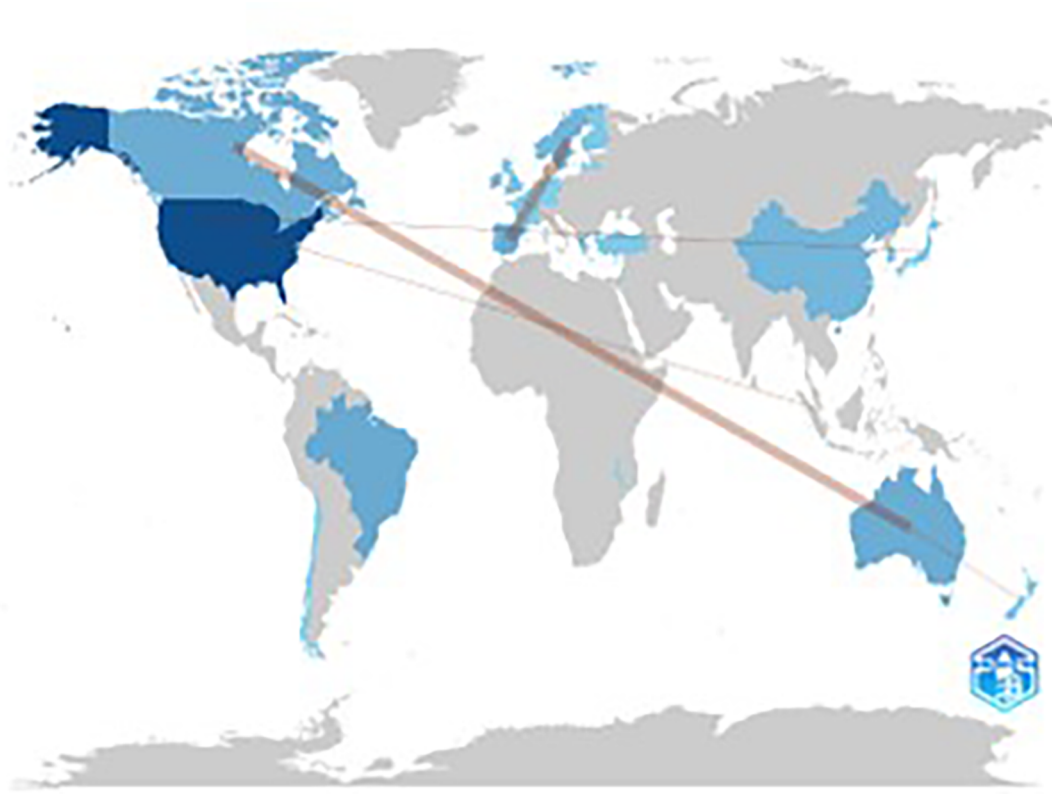

FIGURE 8
Map of collaboration between countries.

State University, Korea National Sport University, the Norwegian School of Sport Sciences, the University of Alberta, and the University of Utah.

The third node (blue) focused on the Chinese University of Hong Kong, which collaborated with Nanyang Technological University, Queensland University of Technology, the University of Jyväskylä, and the University of New Hampshire, although this network was weaker than the others, with only two shared documents.

Finally, the fourth (yellow) and fifth (violet) nodes involved three and two institutions, respectively, with Wisconsin University and Kent State University serving as the main citation hub.

Table 4 shows the 10 journals that published the greatest numbers of articles. Physical Education and Sport Pedagogy was the most productive journal ($n = 11$), followed by Movimento ($n = 9$). In a third-place tie were Adapted Physical Activity Quarterly and European Physical Education Review, each with eight articles.

Of these journals, 55% published only one article, while the rest ($n = 13$) accounted for 80% of the publications. Among the 10 most productive journals, Adapted Physical Activity Quarterly accumulated the highest citation number ($n = 330$), followed by Physical Education and Sport Pedagogy ($n = 326$).

Of the 29 journals analyzed, 14 were classified Q1 (48.3%), 5 were Q2 (17.2%), 4 were Q3 (13.8%), and another 4 were Q4 (13.8%). The remaining two journals had no impact factor (IF): One was newly created and the other had been removed from WoS. Overall, 65.5% of the studies were published in high-impact journals (Q1 or Q2).

The 29 journals had IFs ranging from 0.7 (Journal of Sport Psychology) to 8.0 (Qualitative Research in Sport, Exercise and Health). We identified 13 journals with IFs ranging from 0.6–2.0, 11 journals with IFs ranging from 2.1–3.9, and 3 with IFs greater than 4.0.

The top 10 journals published 73.5% of the articles and accounted for more than 81.7% of the total citations (1,492 citations). Adapted Physical Activity Quarterly had the highest citation number ($n = 330$), and the average number of citations per article was 22.

Figure 11 presents the ten most cited publications on Physical Education practicums. The top article was by Deasy et al. (47); it was published in PLOS ONE, and received 161 citations. Titled "Psychological Distress and Coping amongst Higher Education Students: A Mixed Method Enquiry," this study examines psychological distress among student interns within teacher and nursing education, and how these stressors affect their health and academic performance.

The second most commonly cited article was a review published in 2012 by Qi and Ha titled "Inclusion in Physical Education: A Review of Literature" that received 139 citations. This review analyzed empirical studies on inclusion in Physical

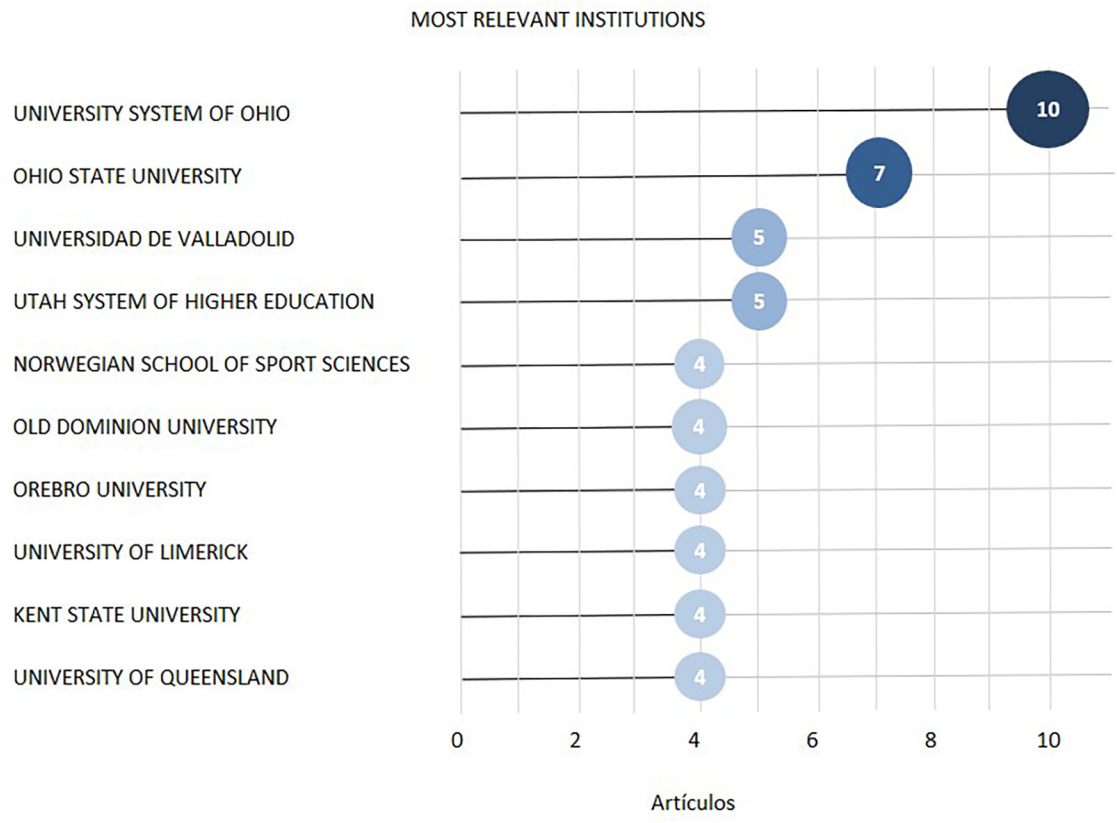

FIGURE 9
Most relevant institutions according to the number of articles published. (Authors' creation).

TABLE 3 The 10 institutions with the highest citation numbers per document.

Institution	Country	Np	Nc	Na	H index
University System Of Ohio	United States	10	352	35.2	9
Ohio State University	United States	7	283	40.43	6
Universidad De Valladolid	Spain	5	235	47	4
Utah System of Higher Education	United States	5	52	10.4	3
Norwegian School of Sport Sciences	Norway	4	62	15.5	4
Old Dominion University	United States	4	71	17.75	3
Orebro University	Sweden	4	210	52.5	3
University of Limerick	Ireland	4	217	54.25	3
Kent State University	United States	4	79	23.25	4
University of Queensland	Australia	4	113	28.25	4

Np, number of publications; Nc, number of citations; Na, average number of citations per article.

Education over the past 20 years and proposed recommendations for future research (48).

The third highest ranked article, by Varea and González-Calvo (49), has been cited 110 times. Titled "Touchless Classes and Absent Bodies: Teaching Physical Education in Times of COVID-19"and published in Sport, Education and Society, this paper explored how the effects of the COVID-19 pandemic have compromised Physical Education practices and the professional development of future Physical Education teachers.

Two studies by Varea and González-Calvo appeared in the top 10 of the most relevant and cited documents, occupying positions 3 and 7. Both works addressed the effects of COVID-19 on students in Physical Education practices. Likewise, the studies by Hodge et al. (2002 and 2003) also appeared in the top 10, at positions 5 and 9; were cited 86 and 55 times, respectively; and were published in Adapted Physical Activity Quarterly.

4 Discussion

In recent years, bibliometric studies have grown considerably because they can offer useful indicators on the evolution of science, identify new lines of research, and highlight emerging fields. This study, to the best of our knowledge, represents the first global bibliometric analysis of the literature related to Physical Education practicums, providing an overview of the focal points, themes, and research frontiers in this area.

The data analyzed were collected from 83 articles on practices related to Sports Sciences, specifically in Physical Education, published in the SSCI and SCIE databases. Using tools such as VOSviewer and the R Bibliometrix package (version 4.2.2), this study revealed an increasing trend in the number of annual

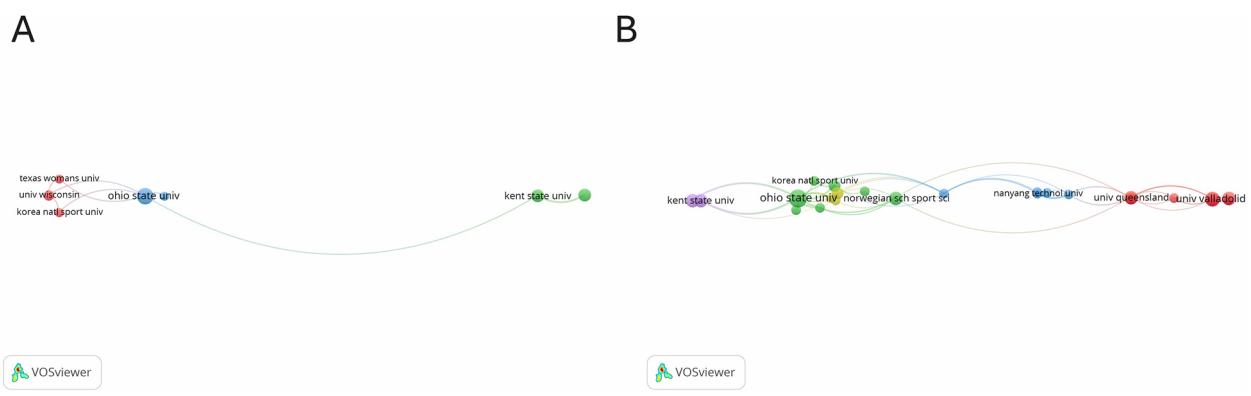

FIGURE 10
(A) institutional collaboration networks. (B) Institutional citation networks.

TABLE 4 The top 10 research journals for physical education practicums.

Journal title	Np	Nc	Na	Impact factor (2023)	Quartile
Physical Education and Sport Pedagogy	11	326	29.64	2.9	Q1
Movimento	9	26	2.89	0.6	Q3
Adapted Physical Activity Quarterly	8	330	41.25	1.7	Q2
European Physical Education Review	8	152	19	2.6	Q1
Sport, Education and Society	7	225	32.14	2.3	Q1
Journal of Teaching in Physical Education	5	57	11.4	1.8	Q2
International Journal of Disability Development and Education	4	171	42.75	1.1	Q3
Teaching and Teacher Education	4	104	26	4.0	Q1
Quest	3	28	9.33	1.6	Q2
European Journal of Teacher Education	2	73	36.5	3.0	Q1

Np, number of publications; Nc, number of citations; Na, average number of citations per article.

publications, with a notable increase starting in 2010, and with the highest output occurring in 2018 and 2022. Previous research, such as that by Moy and Rossi (15), has emphasized the growing interest in the formative practices of future Physical Education teachers, suggesting that the scientific output on this topic has yet to mature, which suggests sustained growth in the upcoming years. Similarly, the study by Westerlund (50) suggested that further research in this area is necessary. Likewise, it highlighted the need to better understand the meaning of teaching Physical Education as a practical activity and how the meaning of teaching Physical Education as didactic knowledge is continuously established during the practicum. The keyword co-occurrence analysis revealed three predominant themes of interest—"attitudes," "Physical Education," and "student teachers"—which were the key points that attracted the attention of the research community.

The co-authorship analysis revealed the involvement of 198 authors, with an average of 2.95 authors per article, indicating a relatively low level of collaboration compared to similar studies (29, 32). As noted by Mattsson et al. (51), this type of analysis does not always clearly identify individual contributions in collaborative works. Traditionally, the first author is considered the primary contributor, while the last tends to take on a supervisory role (52).

Regarding academic productivity, the h index was uniformly distributed among the most prominent authors, in line with the size of the scientific subcommunities that supported a study's citation number (43). This trend highlights the importance of continuing to foster scientific collaboration, especially in a context in which interdisciplinary and international work is increasingly important (53) and highly valued by scientific evaluation agencies (54).

At the institutional level, the analysis revealed the lack of a solid collaboration network among the field's authors. This fragmentation could be explained by the diversity of educational systems and national legislation types, as local contexts may prevent studies from being comparable or from being able to generalize results globally (50). Nevertheless, some countries—such as Australia, Sweden, the United States, and Brazil—exhibited extensive international cooperation networks, which underscores the importance of collaboration in scientific research (55–57).

In terms of the geographic distribution of the scientific output, advanced economies such as China, North America, and Western Europe led in the publication number. Undoubtedly, these regions can considerably support scientific production because they have strongly developed economies and access to the most innovative and advanced research (58). However, Brazil was the only Latin American country among the top ten producers, possibly due to its greater investment efforts in education (17). Other studies have identified similar patterns regarding the limited participation of regions such as Africa and Latin America in global production, a trend linked to factors such as lower levels of research funding and the lack of institutional development (59, 60).

The analysis of the journals with the highest publication number confirmed that those specializing in Physical Education pedagogy—such as Physical Education and Sport Pedagogy, Movimento, and European Physical Education Review—accounted for a large portion of the work in this field. These

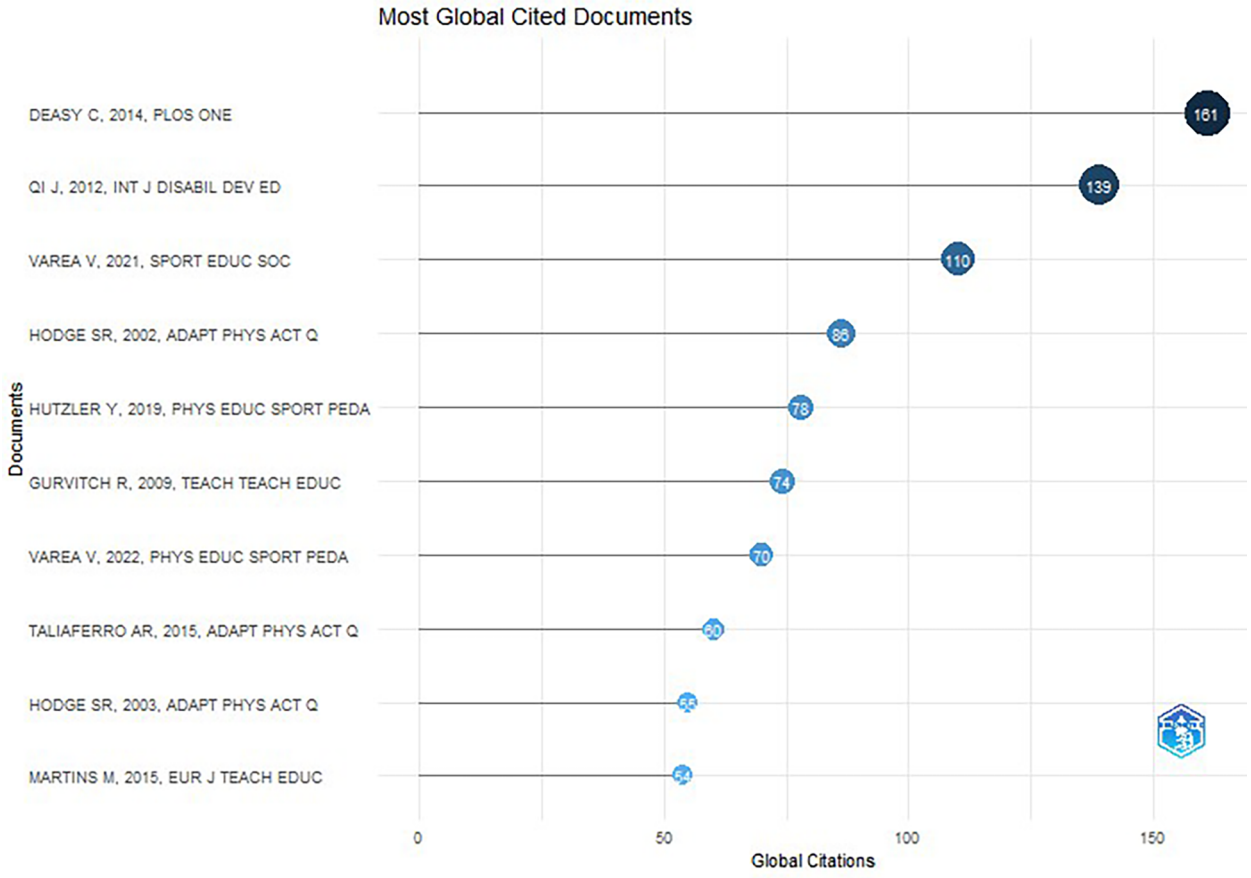

FIGURE 11
Documents cited most worldwide.

results are consistent with Bradford's Law, which explains the concentration of scientific productivity in a small core of journals (61). Publishing in high-impact journals offers numerous advantages, such as recognition in the scientific community and career advancement (62, 63).

Finally, recent changes in journal classification by Clarivate Analytics, particularly the extension of IFs to journals in the Arts and Humanities Citation Index and the Emerging Sources Citation Index, may influence the perception of impact indices and quartiles. This development presents new challenges for evaluating publication quality and conducting bibliometric analyses (64).

5 Conclusions

To the best of our knowledge, this is the first bibliometric study to analyze Physical Education practicums on a global scale. The results reveal considerable growth in research on this topic, with a noticeable increase in publications starting in 2010. Three predominant themes were identified: "attitudes," "Physical Education," and "student teachers." However, low collaboration among authors was observed, possibly due to the global fragmentation of educational systems and differences in national legislation. Countries like Australia, Sweden, the United States, and Brazil demonstrate strong international cooperation networks. Geographically, advanced economies dominate scientific output, while regions such as Africa and Latin America have limited participation, likely due to lower funding and institutional development. Finally, journals specializing in Physical Education pedagogy account for most of the publications, following Bradford's Law. Recent changes in journal classification may influence the perception of impact indices and publication quality.

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

VH-G: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing –

original draft, Writing – review & editing. JC-T: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing – review & editing. CJ-D: Funding acquisition, Investigation, Methodology, Visualization, Writing – review & editing. JR-M: Formal analysis, Funding acquisition, 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.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

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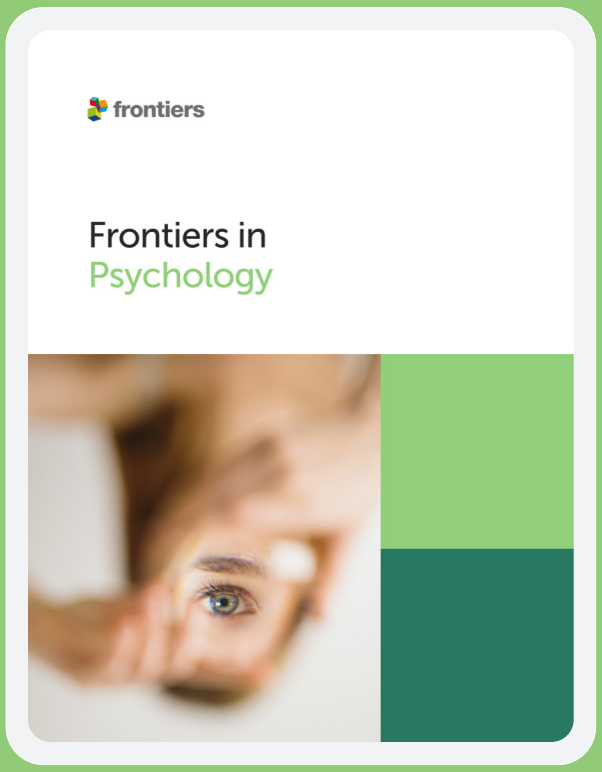

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