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Psychological factors in physical education and sport, volume IV

Edited by
Manuel Gómez-López, Carla Maria Chicau Costa Borrego, Marianna Alesi and David Manzano Sánchez

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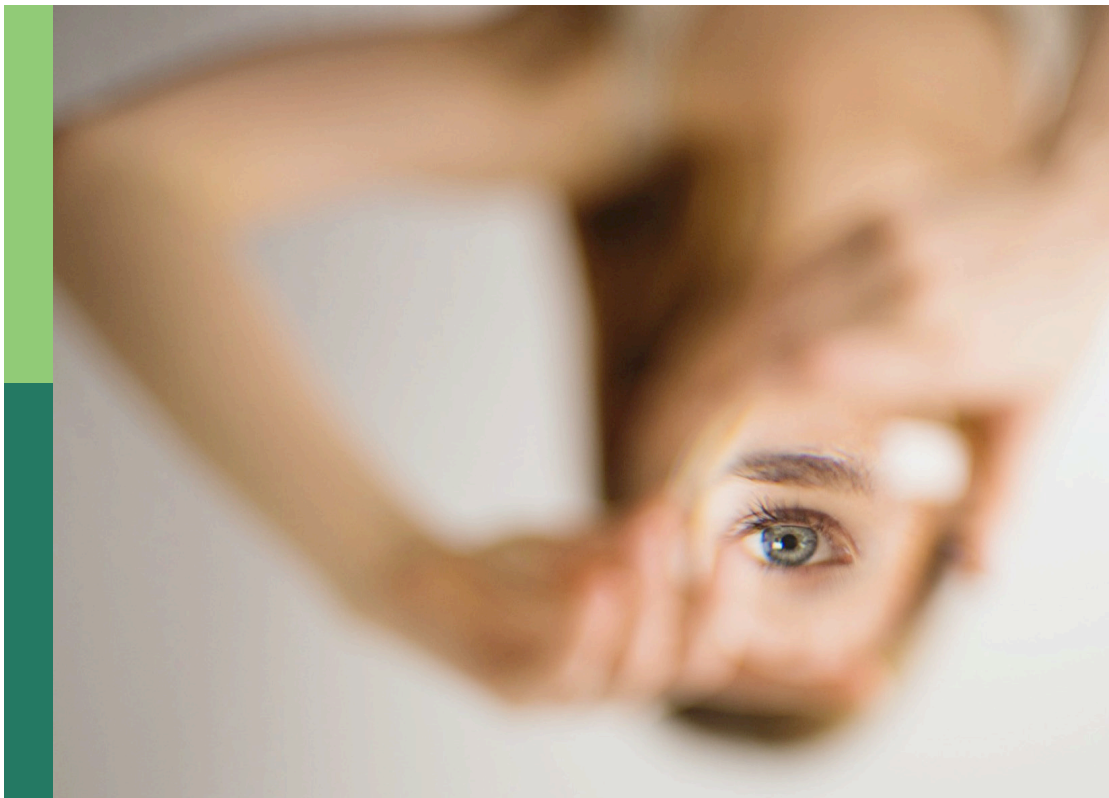

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Psychological factors in physical education and sport, volume IV

Topic editors

Manuel Gómez-López — University of Murcia, Spain

Carla Maria Chicau Costa Borrego — School of Sports of Rio Maior, Polytechnic Institute of Santarém, Portugal

Marianna Alesi — University of Palermo, Italy

David Manzano Sánchez — University of Almeria, Spain

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EDITED AND REVIEWED BY
Miguel-Angel Gomez-Ruano,
Universidad Politécnica de Madrid, Spain

*CORRESPONDENCE
Manuel Gómez-López
✉ mgomezlop@um.es

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Editorial: Psychological factors in physical education and sport – volume IV

Carla Chicau Borrego[1], Manuel Gómez-López[2]*, Marianna Alesi[3] and David Manzano-Sánchez[4]

[1]Sport Sciences School of Rio Maior, Polytechnic Institute of Santarém - Sport Physical Activity and Health Research & INnovation Center, Santarem, Portugal, [2]Department of Physical Activity and Sport, Faculty of Sports Sciences, University of Murcia, Murcia, Spain, [3]Department of Psychology, Educational Sciences, and Human Movement, University of Palermo, Palermo, Italy, [4]Department of Education, Faculty of Education Sciences, University of Almería, Almería, Spain

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motivation, education, sport, physical education, psychological wellbeing

Editorial on the Research Topic
Psychological factors in physical education and sport – volume IV

This Research Topic is the fourth volume of Psychological Factors in Physical Education and Sport and aims to collect the latest research on factors influencing physical and psychological wellbeing and adherence to physical activity in the context of sports and physical education classes. The research and development of these psychological variables can lead to:

Fostering a supportive and inclusive environment that promotes lifelong fitness and health

Belando-Pedreño et al. designed and implemented educational programs at different stages of human development that promote emotional competencies, interpersonal competencies, adequate levels of healthy physical activity, adherence to the Mediterranean diet, and a more active physical and social lifestyle on a physical and social level. In order to identify effective strategies to improve the quality of physical education systems, Jaeuk et al. undertook research that examines the nuances of educational culture, specifically focusing on the psychological experiences of early adolescents within physical education classes. Within the same context, research by Gomez-Paniagua et al. aimed to evaluate the levels of Life Satisfaction of Physical Education students in primary and secondary education in a region in southwestern Spain (Extremadura), analyzing the possible influences of gender and environment of residence.

Positive attitudes toward physical activity have consistently been linked to healthy behaviors. The study by Nie aimed to contribute to the understanding of the relationship between attitudes, self-generated information, and physical activity among university students. It also sought to enhance knowledge of the effectiveness of attitude change in the domain of exercise and identify the mechanisms through which this change occurs, with the goal of promoting exercise behavior in the context of sports.

Globally, there is a persistent public health concern regarding the high prevalence of overweight and obesity. Hu et al. investigated the developmental of obese junior high

school students, focusing on the characteristics of physical education is crucial. Engaging in regular physical activity, according to Wu et al., positively predicts school adaptation among Chinese junior high school students through resilience and coping styles. Defined as a problematic behavior, mobile phone dependence was analyzed by Mei et al. in a review article, which explored the individual and environmental factors, neurobiological mechanisms, and theoretical models associated with this Research Topic in athletes.

The fundamental role of motivation: Recognizing the type of motivation that drives athletes and participants is essential for coaches and educators in crafting training programs that tap into an individual's inner drive, while also fostering a sense of external reward and recognition.

Grounded in self-determination theory, Kruse et al. a examined a multidimensional measurement of support of the basic psychological needs and the individual and combined effects on the development of intrinsic motivation and perceived competence in physical education. In another study, Kruse et al. b presented a measurement model of instructional quality that has proven to be one of the strongest predictors of educational outcomes, such as achievement and motivation. Findings by Yu et al. contributed to the theoretical frameworks of sports psychology and educational psychology by emphasizing the pivotal role of leisure satisfaction and mental toughness in the psychological development of individuals.

Psychological theories and constructs may not be universally applicable due to cultural differences. What is considered a psychological need in one culture may not hold the same significance in another. Researchers must be cautious when generalizing findings from one country to another. Cultural factors can influence an athlete's perception of their needs and how they experience fulfillment (Melesse et al.).

Managing Stress and Anxiety. Stress and anxiety are natural reactions to the competitive nature of sports, but how athletes and coaches manage these emotions can drastically affect their performance. Zhou et al. examined how the characteristics of competitive anxiety impact sports performance across different phases of competitive preparation, alongside its correlation with trait anxiety. Exploring sports participation, muscle-strengthening exercise, and active commuting with comorbidity of depression and anxiety among Chinese children and adolescents, Feng et al. concluded that sports can help relieve anxiety and depression.

Mind wandering (MW) among athletes during training and competition can lead to poor performance. Focus and concentration are often the deciding factors in close competitions. However, Li et al. showed that MW has also been found to have positive effects. With a sample of college students, Liu et al. examined the association between physical activity and negative emotions, specifically depression, anxiety, and stress. In addition, they explored the mediating effects of psychological resilience and coping styles to offer theoretical and practical insights for mitigating students' negative emotions.

Coaches play an important role in sports. Yu and Cheng concluded that reducing emotional exhaustion and negative coping, enhancing emotional support, and improving the academic titles of coaches can help reduce job pressure and occupational burnout among competitive sports coaches. Ferreira et al., in a systematic review, emphasized the importance of social support for coaches in both their personal and professional lives, noting its positive effects and the negative consequences of its absence.

Leadership in sports involves developing individuals, fostering teamwork, and creating a positive environment that promotes growth and success. Centered on coaches, Zhu et al. conducted a systematic review and meta-analysis of Chinese coach leadership and its impact on athlete satisfaction and cohesion. The autonomy-supportive coaching style is recognized for its positive impact on athletes' wellbeing and performance. Su et al. aimed to integrate the autonomy-supportive and laissez-faire coaching styles within the same measurement framework .

On the field, when faced with complex foul situations, referees must make swift and accurate decisions, Wang et al., in the framework of decision-making, examined how soccer referees make decisions about issuing yellow cards for fouls.

Based on these theoretical premises, this Research Topic aimed to address essential questions and collect the most recent research on factors influencing physical and psychological wellbeing, as well as adherence to PA, in the context of physical education classes and sports.

Author contributions

CB: Writing – original draft. MG-L: Writing – review & editing. MA: Writing – review & editing. DM-S: Writing – review & editing.

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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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Nieves Gutiérrez Ángel,
University of Almeria, Spain
Sima Zach,
Academic College at Wingate, Israel

*CORRESPONDENCE
Weixin Dong
✉ dongweixin@hunnu.edu.cn
Chunxia Lu
✉ luchunxia@hunnu.edu.cn

†These authors have contributed equally to this work and share first authorship

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Physical activity and school adaptation among Chinese junior high school students: chain mediation of resilience and coping styles

Xinbo Wu†, Junwen Liang†, Jiaxi Chen, Weixin Dong* and Chunxia Lu*

Department of Sport Education, Hunan Normal University, Changsha, Hunan, China

Background: As a crucial juncture in students' educational journey, junior high school presents challenges that profoundly influence well-being and academic performance. Physical activity emerges as a pivotal factor shaping the holistic development of junior high school students. Beyond its recognized impact on physical and mental health, engaging in regular physical activity proves effective in augmenting students' adaptability to school life. Despite its importance, the mechanisms through which physical activity influences school adaptation in junior high school students remain understudied in academic research.

Objective: In exploring the potential mechanisms, this study aims to validate the mediating roles of resilience and coping styles by examining the association between physical activity and school adaptation among junior high school students.

Methods: This study employed cross-sectional survey approach among junior high school students in China. Through the convenience sampling, 1,488 participants aged from 12 to 16 years old (Average age = 13.59, SD = 1.017) from two Junior high schools in Changsha City, Hunan Province were recruited to complete the Physical Activity Scale, School Adaptation Questionnaire for Junior High School Students, Resilience Scale for Adolescents, and Simple Coping Styles Questionnaire. For data analysis, the SPSS 26.0 and Amos 26.0 were used for statistical processing.

Results: The results showed that physical activity exhibited a significant correlation with school adaptation ($r = 0.656$, $p < 0.001$). Resilience, positive coping style and negative coping style played partial mediating roles between physical activity and school adaptation, with the effect size were 0.229, 0.170, 0.171. The chain mediation effect size of resilience and positive coping style was 0.042, while the chain mediation effect size of resilience and negative coping style was 0.050.

Conclusion: Physical activity positively predicts Chinese junior high school students' school adaptation through resilience and coping styles, suggesting that junior high school students should engage in regular physical activity, so as to improve their resilience and positive coping styles, mitigating negative coping styles, thus promoting their school adaptation.

KEYWORDS

junior high school students, physical activity, school adaptation, resilience, coping styles

Introduction

School adaptation (SA) is defined as students' adaptation and adjustment to various aspects of school life, encompassing academic performance, interpersonal relationships, extracurricular activities, and attitudes toward school (Tomás et al., 2020). If a student is able to comprehensively achieve educational objectives, successfully complete academic pursuits, and acquire effective communication skills within the school environment, while fostering a positive outlook and values, and developing a healthy personality, then it can be determined that the student has attained a high level of school adaptation (Chen, 2003). Researches showed that successful school adaptation positively enhance students' academic achievement (Zysberg and Schwabsky, 2021), interpersonal skills (Kiuru et al., 2020), life perspectives (Zhou, 2012), and positive character traits (Nikooyeh et al., 2017). Therefore, for junior high school students, adapting to school life is a crucial early developmental task (Li et al., 2023), an essential component of their social adaptability (Hou et al., 2022), and a significant indicator of their overall health and development level. However, it's crucial to acknowledge that puberty, along with significant physiology (Henriques-Neto et al., 2023), psychological (Vijayakumar et al., 2023), and socio-emotional changes (Ding et al., 2023), brings various pressures impacting academic performance and interpersonal relationships (Tan et al., 2022). Concurrently, increased academic competition and a heavy workload add to the burden (Laube and Fuhrmann, 2020). Inability to effectively adapt to these modifications can potentially lead to maladaptation within the educational setting. Statistics indicate that approximately 18 to 35% of Chinese adolescents experience maladaptation issues in school (Wang, 2023). These issues not only significantly hinder students' academic progress but may also lead to the development of psychological problems (Chen et al., 2023) such as depression and anxiety, as well as behavioral issues (Wu et al., 2023) like aggression and misconduct. Consequently, these challenges pose a potential threat to the growth of students and the stability of society. As a result, supporting students in effectively adapting to the school environment and managing challenges is of utmost importance during this critical stage.

Previous studies underscore the vital role of physical activity (PA) in fostering students' overall well-being. Engaging in physical activity fortifies resilience (Zach et al., 2021; Guo and Liang, 2023), enhances concentration (Ou et al., 2023) and promotes positive coping strategies (Wu, 2012) and academic performance (Zhu et al., 2021). Physical activity also proves cost-efficient in enhancing school adaptation, presenting a more economical alternative than expensive academic interventions (Gao et al., 2023). In addition to physical activity, previous researches highlight the critical roles of resilience and coping styles in shaping students' adaptation to school settings. Nevertheless, a systematic exploration of the correlation among these four elements has been lacking, limiting our comprehensive understanding of their relationship. This study marks the inaugural cross-sectional analysis examining the connection between physical activity and school adaptation, grounded in the resilience theory and social cognitive theory.

Resilience theory asserts that resilience is an ongoing dynamic process (Rutter, 2012), where individuals consistently improve their resilience through continuous learning, experiences, and personal growth (Yeager and Dweck, 2012). Emphasizing the cultivation of positive coping mechanisms within this framework is crucial for effectively managing stress and challenges (Leipold and Greve, 2009). On the other hand, reciprocal determinism is a fundamental concept within Social cognitive theory (SCT) proposed by Bandura (1977), which emphasizes the bidirectional influence among personal factors, environmental influences, and behavior. In other words, individuals do not passively react to their environment, nor are they solely influenced by their internal cognitive processes. Instead, behavior, personal factors, and environmental factors continually interact and influence each other in a dynamic manner. Within this theory, the physical activity and coping styles could be seen as the individual behaviour, and the school environment could be seen as the environmental influences. Resilience may be operationally defined as strength awareness itself—that is, the belief that one can persevere or accomplish goal-relevant tasks across varied challenges and adverse situations. In this definition, psychological resilience would fall squarely within SCT's personal attributes (Lightsey, 2006). Building upon these theoretical foundations, this study establishes chain-mediated research models to explore the correlation between physical activity and school adaptation.

Physical activity and school adaptation

Engaging in physical activity has emerged as a behavior conferring numerous advantages for individuals and society, including physical health, psychological well-being, and social aspects. Primarily, physical activity enhances blood flow and oxygen delivery to the brain (Nay et al., 2021), thereby augmenting students' concentration in academic settings (Haverkamp et al., 2020). Additionally, physical activities possess the capacity to alleviate stress, anxiety, and depression (Singh et al., 2023), with neurotransmitters like endorphins released during exercise contributing to mood improvement and overall well-being (Pahlavani, 2023). Moreover, certain physical activities, like team sports and group exercise classes, frequently involve social interaction. In these settings, individuals collaborate with teammates to achieve common goals, fostering opportunities for socialization. Research suggests that engaging in such activities enhances students' interpersonal skills (Ortega-Gómez et al., 2023), cooperation, and teamwork (Opstoel et al., 2020), culminating in a positive social experience. This positive experience, characterized by a sense of belonging and acceptance within the school environment (Smith et al., 2021), contributes significantly to students' overall well-being (Opstoel et al., 2020).

The mediating role of resilience

Resilience encapsulates an individual's ability to navigate challenges and overcome setbacks by adjusting their mindset when confronted with stress, adversity, or significant setbacks (Luthar et al., 2000). According to resilience theory, despite the negative correlation between adolescent mental health and various stressors, there exists individuals with well-developed psychological states (Werner, 1984). Individuals facing stressful situations may not necessarily experience maladjustment; rather, they may exhibit strong resilience. Several studies have demonstrated a robust association between physical activity and resilience (Moljord et al., 2014; Belcher et al., 2021). Students who engage in elevated levels of physical activity display

heightened resilience (Hu, 2019) and optimism (Kolovelonis and Goudas, 2018) in comparison to their less active counterparts. At the same time, resilience plays a key role as a protective mediator in coping with challenges, managing stress and maintaining emotional stability (Wang, 2023). It provides students with the psychological resources to cope with the complex emotional (Arslan, 2016), academic (Reeve et al., 2020) and interpersonal issues (Liu et al., 2021). These factors significantly influence adaptability to the school environment. Hence, association between resilience and school adaptation may exist.

The mediating role of coping styles

Coping styles encompass the cognitive and behavioral strategies individuals employ when confronted with stress and frustration (Patterson and McCubbin, 1987), with a notable distinction between positive and negative coping styles. Researches have affirmed that physical activity among junior high school students associated with the positive coping styles (Cao and Zhang, 2006; Liu, 2016a). The higher the frequency of engagement in physical activity among students, the more adept they become at coping with problems rather than avoiding them when confronted with challenging situations (Wu, 2012). Moreover, coping styles represent significant variables influencing school adaptation (Zhang et al., 2021). Those accustomed to positive coping styles typically adopt a problem-solving approach rather than an emotionally oriented one (Stanisławski, 2019). They excel in cultivating a positive self-concept (Coelho et al., 2020), and this optimistic mindset proves beneficial in addressing academic (Marsh and Martin, 2011) and social (Miao et al., 2018) challenges. Conversely, junior high school students embracing negative coping styles, such as avoidance or giving up, may encounter difficulties in school environment (Sun et al., 2023).

Chain mediation of resilience and coping styles

Resilience and coping styles are adaptive states displayed by individuals when confronted with stressors and adversities (DiCorcia and Tronick, 2011). Resilient junior high school adolescents, with their robust ability to handle personal and academic challenges, often see obstacles as opportunities for growth and adopt a versatile approach to problem-solving (Song and Li, 2020). This adaptability allows them to navigate academic (De la Fuente et al., 2017) and interpersonal (Guo et al., 2021) pressures with enhanced effectiveness. Conversely, individuals with diminished resilience tend to avoid challenges and exhibit apprehension toward unfamiliar experiences or difficult circumstances (Beasley et al., 2003). These individuals are more sensitive to failures and setbacks, making them susceptible to negative emotions (Yao et al., 2022). Additionally, they may harbor uncertainties about their capabilities and worth, experiencing discomfort in educational and social contexts (Liu et al., 2016).

In summary, this study aims to investigate the correlation between physical activity and school adaptation among Chinese junior high school students, and to examine whether resilience and coping styles serve as chain mediators in this relationship. The hypotheses are as followed: H1 physical activity is positively associated with school adaptation. H2 resilience mediates the relationship between physical activity and school adaptation. H3 coping styles mediate the relationship between physical activity and school adaptation. H4 resilience and coping styles play chain mediating role between physical activity and school adaptation. Figure 1 shows the hypotheses model between physical activity and school adaptation. The insights gleaned from this study contribute to a deeper understanding of the underlying mechanisms and offer a more comprehensive perspective on the factors influencing junior high school students' school adaptation. Moreover, by providing theoretical evidence for innovative interventions and targeted support programs aimed at enhancing students' school adaptation, this study has the potential to benefit not only junior high school students but also individuals across different age groups and educational settings.

Method

Research design

This study employed a cross-sectional to investigate the relationships outlined in the hypotheses. Convenience sampling was employed to select participants from March 2023 to May 2023. The survey adhered to a systematic protocol with explicit permissions secured from the school principal, class teacher, and participating students. Administered class by class during recess, participants were provided specific guidelines for self-completing the comprehensive questionnaire within a designated timeframe. Respecting students' autonomy, the 25-min investigation allowed withdrawal at any point if desired. To ensure confidentiality and data integrity, an immediate on-site recycling process was implemented upon questionnaire completion.

Participants and context

In this study, participants were recruited from a diverse range of schools located across Changsha city, Hunan Province, situated in the southeast region of China. To ensure a comprehensive representation,

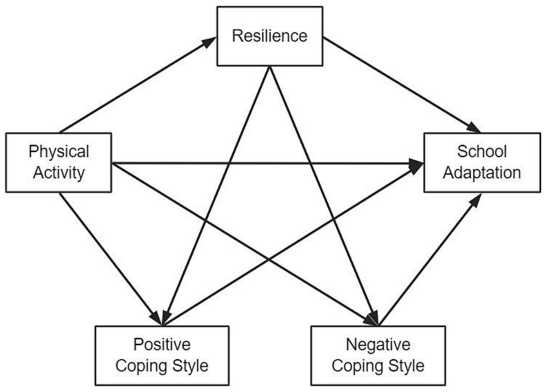

FIGURE 1
Hypothesized model of resilience and coping styles between physical activity and school adaptation,

schools were carefully chosen using random sampling techniques, encompassing both urban and rural areas. Eligible schools were public or private institutions serving students in grades 9–12, with a minimum enrollment of 1,000 students, and a willingness to partake in the study. Ultimately, participants were selected using convenience sampling from two junior high schools located in Changsha. The study involved distributing questionnaires to a total of 1,630 students across 43 classes, after excluding duplicated or inconsistently answered questionnaires, a final valid sample of 1,488 questionnaires was obtained, resulting in an effective response rate of 91.2%. The participants included 769 male and 719 female students, distributed across the three school years (500 in year one, 493 in year two, and 495 in year three), with an average age of 13.59 ± 1.017 years (see Table 1). All invited participants are voluntary, thus confidentiality has been guaranteed, and written informed consent of all participants' parents or guardians has been obtained.

Instruments

The formal questionnaire employed in this research comprises two principal sections. The first section is dedicated to collecting essential demographic information about the respondents, encompassing variables such as gender, age, and grade level. The subsequent section incorporates well-established scales to assess various dimensions, including physical activity, resilience, coping styles, and school adaptation.

To evaluate the physical activity levels of individuals, the well-established Physical Activity Rank Scale (PARS-3) developed by Liang (1994) was utilized. This scale has been widely used among Chinese adolescents (Bai et al., 2022; Zhang and Li, 2023), particularly in cross-sectional studies. This scale encompasses three dimensions: exercise intensity (e.g., How intensely do you engage in physical activity?), exercise time, and exercise frequency. Each dimension is further stratified into five grades. Intensity and frequency of physical activity are rated on a scale from 1 to 5, while time spent on physical activity is rated on a scale from 0 to 4. The total physical activity score is computed by multiplying intensity, time, and frequency, resulting in a score ranging from 0 to 100. A higher score indicates a more substantial level of exercise engagement. In this study, the internal consistency coefficient α of the questionnaire was 0.830.

TABLE 1 The demographics of the participants.

Variables	Categories	Number of participants	Percentage(%)
Gender	Male	769	51.7
	Female	719	48.3
Age	12	216	14.5
	13	509	34.2
	14	467	31.4
	15	257	17.3
	16	39	2.6
Grade	Seventh	500	33.6
	Eighth	493	33.1
	Ninth	495	33.3

The school adaptation Scale, adapted from the revised Questionnaire by Cui (2008), has been extensively employed for assessing school adaptation among junior high school students in China (Wu et al., 2023). Comprising 27 questions (e.g., I was often distracted while studying.), the scale includes dimensions such as Routine Adjustment, Course Adjustment, Teacher-Student Relationship Adjustment, Friend Adjustment, and School Attitude Adjustment. Utilizing a five-point rating system, ranging from "1 = extremely inconsistent" to "5 = extremely consistent", the scale employs reverse scoring for questions 3, 5, 14, 16, and 23. Here, "1 = extremely consistent" corresponds to the highest level of agreement, while "5 = extremely inconsistent" denotes the lowest level. Elevated scores in each dimension indicate a higher level of adaptability to the school environment. In this study, the internal consistency coefficient α of the questionnaire was 0.890.

The resilience Scale for Adolescents, revised by Hu and Gan (2008), comprises 27 questions (e.g., Failure always makes me feel discouraged.) distributed across five dimensions: Goal Focus, Emotional Control, Positive Cognition, Family Support, and Interpersonal Assistance. Utilizing a five-level scoring system, ranging from "1 = extremely inconsistent" to "5 = extremely consistent", the scale employs reverse scoring for questions 1, 2, 5, 6, 9, 12, 15, 16, 17, 21, 26, and 27, with the same rating scale applied. A higher cumulative score across the selected items corresponds to an elevated level of resilience. This scale has been proven to have good validity and reliability among Chinese adolescent (Song and Li, 2020; Guo et al., 2021). In this study, the internal consistency coefficient α of the questionnaire was 0.926.

The Simple Coping Style Questionnaire, developed and consolidated by Xie (1998), consists of 20 items (e.g., When life gets tough, I can find several solutions to my problems or I relieve my worries by eating, smoking, drinking, or taking medication.) categorized into two dimensions: Positive Coping and Negative Coping. Respondents rate each item using a four-point scale, ranging from "0 = extremely inconsistent" to "3 = extremely consistent." Questions 1 to 12 form the Positive Coping style (PCS), while questions 13 to 20 constitute the Negative Coping style (NCS). Higher scores in Positive Coping indicate a propensity to employ positive strategies in the face of challenges, whereas higher scores in Negative Coping suggest a tendency to adopt negative approaches. This scale has been proven to have good validity and reliability among Chinese students (Wu et al., 2020; Zhao et al., 2021). In this study, the internal consistency coefficient α of positive and negative dimension were 0.945 and 0.923, respectively.

Data analysis

The research analyzed the collected data using SPSS 26.0 and Amos 26.0, with a significance level set at 0.05. To address potential common method bias, a Harman's common method bias test was initially conducted using SPSS. Subsequently, a confirmatory factor analysis using Amos. Pearson's correlation analysis was utilized to explore relationships among physical activity, resilience, coping styles, and school adaptation. Lastly, the study delved into examining the mediating effects of resilience and coping styles

through Amos's structural equation modeling, including an assessment of the chained mediating role of mental resilience and coping styles within this framework. The Bootstrap method was applied for evaluating the significance of the intermediate effect, with the samples being replicated 5000 times. The assessment of the mediating effect's significance relied on whether the Bias-Corrected 95% confidence interval (CI) included zero. A non-zero inclusion within the confidence interval signifies a noteworthy mediation effect, whereas zero inclusion implies an insignificant mediation effect.

Common method bias

The data collection method employed in this study relied on self-report measures. It is crucial to acknowledge that such methods carry the potential for common methodology bias, which could influence the research outcomes. To address this concern, Harman's single-factor test method was utilized to examine the presence of common bias within the research data. The Kaiser–Meyer–Olkin (KMO) value, calculated at 0.956 with a significance level of $p < 0.001$, indicated the suitability of the data for exploratory factor analysis. Unrotated principal component analysis, conducted on the variable measurement questions using SPSS 26.0 software, revealed that the first principal component accounted for only 22.86% of the total variation, falling below the critical value of 40%. This suggests that common method deviation did not exert a significant impact on the study's results.

Results and analysis

Correlation analysis

The present study employed Pearson correlation coefficient analysis to assess the strength and direction of the relationship between variables derived from the value of the phase relationship. The findings are presented in Table 2. Notably, the correlation coefficients between any two variables, namely PA, SA, PR, PCS, and NCS, were all statistically significant at a 1% level. Moreover, a significant positive correlation was observed between PA, PR, and PCS, and SA ($r = 0.576$, $r = 0.499$, $r = 0.519$, $p < 0.01$). Conversely, a significant negative correlation was found between NCS and SA ($r = -0.563$, $p < 0.01$), thereby providing preliminary evidence to support the plausibility of the hypothesis proposed in this study. Further investigation is warranted to validate these findings.

Hypothesis testing

Correlation between physical activity and school adaptation

By formulating a structural equation model, this study scrutinizes the correlation between physical activity and school adaptation among junior high school students. The outcomes reveal a statistically significant positive correlation between physical activity and school adaptation ($\beta = 0.656$, $p < 0.001$), thereby substantiating hypothesis H1.

The mediation effect of resilience

Based on the findings presented in Table 3, it is evident that in the analysis involving the mediating variable of resilience, the indirect effect is quantified at 0.229, 95% CI (0.190, 0.270). Moreover, the direct effect is recorded as 0.431, 95% CI (0.369, 0.485). This indicates that resilience plays a partial mediating role in the relationship. Additionally, the mediating effect contributes to 34.7% of the total effect. These findings provide substantial support for Hypothesis H2, which posits that resilience acts as a mediator between physical activity and school adaptation.

The mediation effect of coping styles

Moving to Table 4, the results of the test conducted with positive coping style as the mediating variable are presented. The indirect effect is determined to be 0.170, 95% CI (0.140, 0.204). The direct effect is identified as 0.489, 95% CI (0.428, 0.548). This suggests that positive coping style plays a mediating role in the relationship, and the mediating effect accounts for 25.8% of the total effect. Similarly, Table 5 displays the results of the test conducted using negative coping style as the mediating variable. The indirect effect is calculated as 0.171, 95% CI (0.146, 0.202). The direct effect is found to be 0.490, 95% CI (0.434, 0.540). This suggests that negative coping style plays a partial mediating role, and its mediating effect accounts for 25.9% of the total effect. Both positive and negative coping styles exhibit partial mediating effects between physical activity and school adaptation, supporting Hypothesis H3.

The mediation effect of resilience and coping styles

Following an independent examination of the mediating effects of resilience and coping style, this research proceeded to explore the interconnected mediating effects of these two variables as mediators. Consequently, a pathway model was constructed to illustrate the influence of physical activity on school adaptation, with resilience and coping style serving as mediating factors. Please refer to

TABLE 2 Correlation coefficient matrix of research variables.

Variate	M	SD	PA	SA	PR	PCS	NCS
PA	30.14	24.56	1				
SA	96.94	13.84	0.576**	1			
PR	87.31	18.54	0.581**	0.499**	1		
PCS	19.41	7.45	0.475**	0.519**	0.398**	1	
NCS	8.65	6.36	−0.356**	−0.563**	−0.281**	−0.354**	1

**Indicates significance level $p < 0.01$. PA indicates physical activity, SA indicates school adaptation, PR indicates resilience, PCS indicates positive coping styles, NCS indicates negative coping styles.

TABLE 3 Resilience bootstrap mediation effect tests.

Path	Effect size	Bias-corrected 95%CI		Effect ratio
		Lower	Upper	
Total effect	0.660	0.609	0.705	
Direct effect	0.431	0.369	0.485	68.8%
Indirect effect	0.229	0.190	0.270	34.7%

All coefficients are standardized, and the following empirical data are standardized results.

TABLE 4 Positive coping style bootstrap mediation effect tests.

Path	Effect size	Bias-corrected 95%CI		Effect ratio
		Lower	Upper	
Total effect	0.659	0.607	0.705	
Direct effect	0.489	0.428	0.548	74.2%
Indirect effect	0.170	0.140	0.204	25.8%

TABLE 5 Negative coping style bootstrap mediation effect tests.

Path	Effect size	Bias-corrected 95%CI		Effect ratio
		Lower	Upper	
Total effect	0.661	0.609	0.707	
Direct effect	0.490	0.434	0.540	74.1%
Indirect effect	0.171	0.146	0.202	25.9%

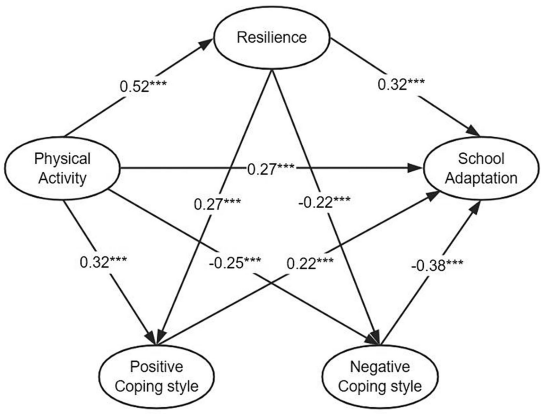

FIGURE 2
Mediating roles of resilience and coping styles effect between PA and SA. ***$p < 0.001$.

TABLE 6 Test of chain mediation effect.

Path	Effect size	Bias-corrected 95%CI		Effect ratio
		Lower	Upper	
Total effect	0.680	0.627	0.725	
Direct effect	0.274	0.209	0.334	40.3%
Indirect effect	0.406	0.361	0.54	59.7%
PA → PR → SA	0.166	0.133	0.202	24.4%
PA → PCS → SA	0.069	0.049	0.093	10.1%
PA → NCS → SA	0.097	0.067	0.128	14.3%
PA → PR → PCS → SA	0.030	0.020	0.043	4.5%
PA → PR → NCS → SA	0.045	0.030	0.063	6.6%

PA indicates physical activity, SA indicates school adaptation, PR indicates resilience, PCS indicates positive coping styles, NCS indicates negative coping styles.

Figure 2 for a visual representation of the model. The hypothesis model underwent testing, yielding excellent results in terms of overall model fit: $\chi^2/df = 2.623$, which is less than the recommended threshold of 3. Furthermore, AGFI, GFI, NFI, IFI, TLI, and CFI all exceeded 0.9, indicating a strong fit. Additionally, the RMSEA value of 0.033 is below the recommended threshold of 0.05.

The results of the chain mediation effect test, as presented in Table 6, reveal a significant indirect effect of "physical activity → resilience → positive coping style → school adaptation" with a value of 0.030 (95% CI: 0.020, 0.043). This chain mediation effect accounts for 4.5% of the total effect. Similarly, the indirect effect of "physical activity → resilience → negative coping style → school adaptation" is also significant, with a value of 0.045 (95% CI: 0.030, 0.063). In this case, the chain mediation effect accounts for 6.6% of the total effect. Importantly, the coefficients of both pathways fall outside the range of 0 within the 95% confidence interval, indicating that resilience and coping styles play a significant role in mediating the relationship between physical activity and school adaptation, thus supporting the validity of Hypothesis H4.

Discussion

The current study explored the relationships among physical activity, resilience, positive coping styles, negative coping styles, and school adaptation among junior high school students in China. The findings illuminated that physical activity not only directly correlates the school adaptation but also exerts an indirect correlation through the pathways of resilience, positive coping styles, and negative coping styles. Five distinct mediation paths were identified: the first involving resilience as a mediating variable, the second featuring positive coping styles as the mediating variable, the third incorporating negative coping styles as the mediating variable, the fourth encompassing resilience and positive coping styles as the dual mediating variables in a chain mediation path, and the fifth involving resilience and negative coping styles as the dual mediating variables in another chain mediation path. This section outlines the major results, which are discussed alongside other relevant literature.

The findings of this research indicated the positive influence of physical activities on the school adaptation of junior high school students, which align with the research findings of Cao et al. (2018) and Gao et al. (2023). Their works indicated that the predictive role of heightened physical activity levels in junior high school students' school adaptation, with a clear association between higher degrees of physical activity and superior levels of school adaptation. Cao also found that regular participation in physical activities enhances adolescents' self-perception skills, facilitating the management of

academic stress (Cao et al., 2018). Involvement in organized physical activity is more beneficial for adolescent's school adaptation, due to an increase in the probability of school integration (Mosoi et al., 2020). In particular, participation in team related physical activity not only provides opportunities for forming new friendships but also eases integration into peer groups through shared interests (Zhang, 2023). Team sports cultivates teamwork spirit among students (Opstoel et al., 2020), fostering favorable peer relationships (Worley et al., 2020). Active engagement in school sports activities increases the likelihood of developing a positive attitude toward school, reinforcing a sense of school belonging and identification with campus culture (Jones et al., 2020). In summary, the involvement of junior high school students in physical activity manifests a multi-dimensional positive impact on their school adaptation, influencing not only their physical well-being but also contributing to academic, social, and emotional growth.

The findings of this research indicated that resilience serves as a crucial intermediary variable in the intricate relationship between physical activity and school adaptation. Previous research highlights the significant contribution of physical activity to students' resilience development (Skinner and Pitzer, 2012; Mosewich et al., 2014). Low frustration experienced in different physical activity contexts (i.e., physical education and leisure-time physical activity) reports high well-being and enjoyment (Warburton et al., 2020), which would equip students with enhanced resilience. Success in physical activity also contributes to an increased sense of self-efficacy among students (Latino et al., 2023), a critical element of resilience. This heightened self-belief empowers students, reinforcing their confidence in academic pursuits (Komarraju and Nadler, 2013) and fostering a positive learning attitude and adaptability (Zimmerman, 2000), thus facilitating their adaptation to the school environment (Nowland and Qualter, 2020). Additionally, students actively participating in high-intensity physical activities demonstrate heightened perseverance and optimism compared to peers with lower activity levels (Huang, 2020), with the varying intensity of these activities further enhancing students' mental endurance (Hu, 2019). A robust connection exists between resilience and school adaptation, where higher resilience correlates with improved emotional regulation (Huang et al., 2023) and social skills (Martinsone et al., 2022), thereby fostering overall school adaptation. Consequently, the mediating role of resilience plays a pivotal part in establishing a connection between physical activity and successful adaptation to school life.

The findings of this research indicated that coping styles act as mediator between physical activity and school adaptation among junior high school students. Put differently, an increase in the physical activity levels of these students corresponds to a likelihood of embracing positive coping styles (Chen et al., 2013; Liu, 2016b; Yang et al., 2020), thereby contributing to an enhanced school adaptation (Zhang et al., 2021). Yang Jian's research reveals a significant positive correlation between the intensity of physical activity and its efficacy in fortifying confidence and determination among junior high school students (Yang et al., 2020). Specifically, those engaging in elevated levels of physical activity exhibit heightened resilience and unwavering personal resolve. When confronted with challenges, this demographic transitions from evading difficulties to actively seeking solutions and confronting obstacles, fostering heightened adaptability to the school environment (Bao, 2012; Shi et al., 2015). On the contrary, students who are not very physically active often resort to negative coping styles (Cheng et al., 2023), which are linked to insufficient adaptation to school (Han et al., 2016). Previous researches have also found that junior high school students with a negative attitude toward physical activities often avoid participating in such pursuits, skip regular exercise, or deviate from established training routines (Nelson et al., 2010). Students accustomed to employing negative coping styles may resort to evasion or surrender when facing life or academic challenges (Cherkil et al., 2013), leading to a decline in self-efficacy and the accumulation of negative emotions (Qu et al., 2023). This renders it more challenging for them to navigate the pressures and challenges inherent in school life and learning. Furthermore, using negative coping styles may result in conflicts and isolation with peers and teachers (Henderson et al., 2003), leading to feelings of loneliness or exclusion (Elahe et al., 2017). It would impact the relationships between students and their peers and teachers (Shen et al., 2021), leading to a decline in the level of school adaptation. In summary, it can be observed that both positive and negative coping styles play a mediating role in the connection between physical activity and school adaptation in junior high school adolescents.

The findings of this research indicate the relationship between physical activity and school adaptation, intricately mediated by resilience and coping styles among junior high school students. Specifically, active participation in sports activities significantly contributes to the cultivation of resilience (Belcher et al., 2021). Elevated resilience levels enhance the likelihood of adopting positive coping styles. These positive coping mechanisms play a pivotal role in shaping students' adaptation within school. Conversely, students who abstain from or resist participation in physical activity correlates with diminished resilience compared to those with elevated physical activity (Li et al., 2022). Individuals with lower resilience levels exhibit inadequate coping abilities when faced with setbacks and pressures (Zou et al., 2024), such as avoidance and self-blame (Wang et al., 2020). These negative coping mechanisms impede effective problem resolution, leading to the postponement or neglect of issues and, consequently, exacerbating challenges in school adaptation (Wu, 2012). In summary, a robust correlation exists between individuals' coping styles and their resilience. Positive coping styles and coping flexibility demonstrate a positive association with higher resilience, whereas negative coping styles exhibit a negative association with lower resilience.

Research deficiencies and future directions

Although this study has provides valuable insights into fostering adaptive development among junior high school students within the school environment, some limitations also require special attention. Firstly, the cross-sectional design impedes the establishment of definitive causal relationships between variables without longitudinal data. Secondly, although the sample size meets statistical criteria, the limited geographical distribution coverage, confined to two middle schools in Changsha, Hunan Province, may not adequately represent the characteristics of the entire population. Lastly, due to time and energy constraints, the study primarily employs Likert scale-based questionnaires, lacking in-depth interviews with respondents.

In future studies, researchers could enhance the study's depth by incorporating longitudinal follow-up or experimental interventions to gain a more comprehensive understanding of how physical activity influences the school adaptation of junior high school students. Future investigations should aim to broaden the sampling area, improving the generalizability of research findings and yielding more robust conclusions. Additionally, researchers can consider using a combination of quantitative and qualitative research methods to collect diverse data and materials, contributing to a richer analysis of the phenomena under investigation.

Conclusion

This study indicated the correlation between physical activity and the school adaptation (Mosoi et al., 2020; Yan et al., 2020; Bai et al., 2022; Qin and Qin, 2023), resilience (Moljord et al., 2014; Hu, 2019; Belcher et al., 2021), coping styles (Cao and Zhang, 2006; Liu, 2016a) of junior high school students which aligns with previous researches. Furthermore, the resilience and coping styles of these students emerge as key factors impact school adaptation, each playing a distinct and partial mediating role in the relationship between physical activity and school adaptation. More interestingly, the intricate dynamics of this relationship are revealed as resilience and positive coping style collaboratively form a chain mediating role between physical activity and school adaptation, alongside resilience and negative coping styles.

Based on these findings, recommendations propose that: (i) Schools and parents should prioritize physical activity for junior high school students. Programs should offer diverse activities like team sports or individual exercises to cater to different preferences. (ii) Given the importance of resilience, efforts should be made to teach resilience-building strategies in family education, school curricula, and extracurricular activities. This can include workshops or training sessions aimed at developing resilience skills. (iii) Family, schools, and educators should focus on fostering positive coping styles among students. Support and resources should be provided to help students develop effective coping strategies, such as seeking social support and problem-solving. Interventions should address negative coping strategies through counseling or peer support programs. (iv) Recognize the connection between resilience, coping styles, and physical activity in influencing school adaptation. Future research and interventions should consider this complex interplay and involve collaborations between educators, psychologists, and health professionals to develop comprehensive strategies. By implementing these suggestions, families and educational institutions can enhance the school adaptation and overall well-being of junior high school students.

Data availability statement

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

Ethics statement

Ethical approval was not required for the study involving humans 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

XW: Conceptualization, Data curation, Formal analysis, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. JL: Conceptualization, Data curation, Investigation, Methodology, Project administration, Software, Validation, Writing – original draft, Writing – review & editing. JC: Data curation, Formal analysis, Validation, Software, Writing – review & editing. WD: Conceptualization, Project administration, Resources, Supervision, Visualization, Writing – review & editing. CL: Conceptualization, Project administration, Resources, Supervision, Visualization, 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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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Luis Leitão,
Escola Superior de Educação,
Instituto Politecnico de Setubal (IPS), Portugal
Liliana Ricardo Ramos,
Polytechnic Institute of Santarém, Portugal

*CORRESPONDENCE
Shi Luo
luoshi0604@126.com

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The effects of mobile phone dependence on athletic performance and its mechanisms

Zhengyang Mei, Yuanzhuo Zhang, Qing Fan, Shulai Luo and Shi Luo*

School of Physical Education, Southwest University, Chongqing, China

Mobile phone dependence (also known as internet dependence, MPD), defined as a problematic behavior characterized by excessive use or intermittent craving to use a mobile phone, results in various social, behavioral, and affective problems in daily life. In sports, MPD is directly related to the physical and mental health and sports performance of athletes. The individual and environmental factors, neurobiological mechanisms and theoretical models of MPD affecting athletic performance were analyzed by reviewing previous studies, aiming to construct effective training and development protocols to prevent and control the occurrence of MPD in athletes. At present, athletic performance can be affected by MPD through individual factors and environmental factors. The neurobiological mechanisms between the two are based on the brain reward system and microwave radiation from mobile phones, with athletic performance being restricted by alterations in the corresponding brain regions. Relevant theoretical models mainly include the social cognitive model of self-regulation and the integrative model of self-control, which explain the interrelationship between MPD and athletic performance from the perspectives of athletes' self-regulation and self-control, respectively. As an emerging phenomenon, the influence pathways and mechanisms by which MPD affects athletic performance need to be further investigated. A longitudinal perspective should be adopted to trace the dynamic impact relationship between the two, and developing relevant theoretical frameworks from an interdisciplinary research perspective should be valuable for providing theoretical support for coaches and sports administrators to formulate scientific training protocols and thus improve the mental health of athletes.

KEYWORDS

athlete, mobile phone dependence, sports performance, neurobiological mechanism, theoretical model

1 Introduction

According to the Global Digital Report, the number of unique mobile phone users sits at 5.61 billion at the start of 2024. The latest data from GSMA Intelligence reveals that 69.4% of the world's total population now uses a mobile device. Meanwhile, the 53rd Statistical Reports on Internet Development in China released by the China Internet Network Information Center (CNNIC) shows that the number of internet users in China, as of December 2023, has reached 1.092 billion, with 3.8 and 14.7% of these users being under the age of 10 and between the ages of 10 and 19, respectively. The internet has nearly 200 million adolescent users, and the internet penetration rate among minors has almost

reached saturation. With the increasing use of mobile phones, the associated problems and challenges have become more prominent. Additionally, there is a growing number of individuals who are addicted to, dependent on, or misusing mobile phones (Yu and Sussman, 2020). Mobile phone dependence (MPD) defined as a problematic behavior characterized by excessive use or intermittent craving to use a mobile phone, results in various social, behavioral, and affective problems in daily life (Billieux, 2012; Billieux et al., 2015). Moreover, some studies have adopted the synonymous concepts of MPD, including smartphone dependence (Park, 2019), smartphone addiction (Lopez-Fernandez, 2017), problematic mobile phone use (Harris et al., 2020), and mobile phone overuse (Kawyannejad et al., 2019).

Studies have demonstrated that the frequency and duration of mobile phone usage are important indicators for assessing MPD, and individuals who use mobile phones for more than 4 h per day can be considered potential mobile phone dependents (Song et al., 2023). At present, models of the influence mechanisms of internet addiction have been developed in the field of psychology, which indicate that internet addiction may lead to anxiety and depression, making it difficult to respond to life stress or negative events in a reasonable manner, and that psychological symptoms and pain can be worsened by such behavioral addictions. In the field of sports, mobile phones have significantly improved the lives and training of athletes, who regularly use mobile phones to manage roles and demands across multiple contexts, such as society, family and school (DesClouds and Durand-Bush, 2021). For young athletes, however, a range of physical and mental health problems can easily develop due to MPD, including emotional disturbance, poor sleep quality, difficulties in interpersonal relationship, reduced cognitive function, and attention allocation, which in turn can lead to impaired athletic performance (Encel et al., 2017; Gould et al., 2020; Jones et al., 2021; Ayyildiz and Besler, 2022; Gocer and Oniz, 2023). In recent years, MPD has become a highly significant research topic and has received increasing attention within the filed of sports psychology.

Therefore, this paper analyses and discusses the effects of MPD on athletic performance, the neurobiological mechanisms and relevant theoretical models of MPD affecting athletic performance, and on the basis of which research prospects are proposed, providing a theoretical reference and guidance for subsequent research in this field.

2 Relevant research on the effects of MPD on athletic performance

According to the holistic model of determinants of sports performance proposed by Bangsbo (2015), sports performance can be impacted by individuals' psychological characteristics, physiological states, and external environmental conditions. Similarly, the effects of MPD on athletic performance can also be realized through interactions between individual and environmental factors. For instance, athletes may not be able to focus on training and lose the desire to pursue outstanding athletic performance due to interference with the attention allocation disrupted by MPD. Moreover, athletic performance can be restricted by MPD through weakening positive incentives in the sports environment, including an active training atmosphere, and friendly coach-athlete relationship (CAR). On this basis, the relevant research on the effects of MPD on athletic performance is divided into individual and environmental factors for discussion.

2.1 Individual factors

Athletes not only have to cope with the challenges and pressure of their peers, such as academic task, but also have to weather the additional demands of sports, and invest a great deal of time and energy in training and competition, thus they are subjected to various sources and forms of physical and psychological stress, including losing competitions, sports injuries, interpersonal relationships, further education pressure, future prospects, and personal life encounters (Fiedler et al., 2023). According to the general stress theory, problematic behaviors (e.g., MPD) are rooted mainly in negative emotions caused by stress or stressors, and the corresponding adaptive means will be adopted by athletes with problematic behaviors to alleviate pressure during stressful states (Agnew, 1992; Jun and Choi, 2015). Evidence has suggested that MPD tendencies may be more likely to develop in groups experiencing stress (Mehmood et al., 2021; Zhong et al., 2022). Athletes are susceptible to multiple stressors in life, study and training, which can lead to negative emotions such as anxiety and depression, and mobile phone usage provides an effective means for relieving stress. However, as most athletes have weak self-control, the psychological stress and negative emotions may be further aggravated by excessive use or dependence on mobile phones, which can adversely affect athletic performance (Elhai et al., 2017; Sahu et al., 2019; Ong et al., 2022), and even "choking" during competition. Ivarsson et al. (2017) have argued that adverse physiological reactions can be caused by the stress and anxiety experienced by athletes, including increased muscle tension, mental toughness and reduced neurocognitive and perceptual ability, with athletic performance being impaired. Furthermore, Hamlin et al. (2019) suggested that once the stress generated in academic and training environments exceeds athletes' abilities to cope, athletes become more susceptible to decreased performance, increasing the risk of injury and illness. As a result, stressed athletes may view mobile phone usage as a kind of avoidant coping that allows them to temporarily escape from stressful situations, which in the long run may exacerbate MPD, rendering it unable to have adaptive coping effects, but further worsening psychological pressure and negative emotions, with athletic performance being constrained accordingly and difficult to improve.

Chronic problematic use of mobile phones may also consume the attentional resources and cognitive abilities of athletes (DesClouds and Durand-Bush, 2021; Ong et al., 2022), leading to mental fatigue and limiting athletic performance in training and competition (Fortes et al., 2022a; Alix-Fages et al., 2023). An 8-week randomized and experimental research with parallel groups showed that swimmers who used a smartphone for 30 min before training showed higher levels of mental fatigue ($p = 0.01$) and internal training load ($p = 0.01$), and their 100-m and 400-m freestyle performance gains were inhibited compared with the control group (Fortes et al., 2022b). According to the brain drain hypothesis proposed by Ward et al. (2017), using attentional resources for one cognitive process or task will reduce the resources available for other tasks. Simultaneously, since limited attentional resources are required to support other attentional control and cognitive

processes, the attentional resources occupied by mobile phone usage will not be available for other tasks whose performance will suffer. Moreover, due to the mental fatigue and cognitive decline caused by prolonged exposure to smartphone apps, such athletes' decision-making performance tend to be inhibited while engaging in tasks (Fortes et al., 2019). According to a randomized and experimental research with parallel groups on volleyball players, there was a statistically significant group × time interaction for both attack decision-making performance ($p = 0.03$) and passing decision-making performance ($p = 0.02$). Only athletes in the control group showed improvement in their attack decision-making performance ($p = 0.02$) and passing decision-making performance ($p = 0.01$) compared with athletes in the experimental group who used social media apps on smartphones before training (Fortes et al., 2021). These data corroborate the argument that sustained high cognitive demanding activity (e.g., MPD) led to mental fatigue and impaired decision-making performance in athletes (Smith et al., 2016; Gantois et al., 2020; Trecroci et al., 2020; Staiano et al., 2024). This may be due to the lack of self-regulation in such athletes, with the majority of limited attentional resources being focused on behavioral dependencies, resulting in fewer resources being allocated to athletic performance, reduced decision-making, and thus failure to achieve an optimal state of performance. In conclusion, for athletes with MPD, a large amount of attentional resources may be consumed by prolonged and high frequency mobile phone usage, reducing resource allocation to other cognitive activities, such as training and competition, leading to distraction, wandering and ultimately an inability to focus on current activities (Encel et al., 2017; David et al., 2018).

A body of research has indicated that athletic performance can be impaired by MPD through causing the sleep disturbance and irregular lifestyle (Thun et al., 2015; Romyn et al., 2016; Charest and Grandner, 2020; Gupta, 2023). Sleep is often considered as the key to achieving the optimal athletic performance, and sleep deprivation leads to a variety of physical and psychological consequences, including stress, anxiety, and decreased coping and recovery. Based on the blue light theory, the production of melatonin may be inhibited by the blue light emitted by mobile phones, thus increasing sleep latency and reducing sleep quality in athletes (Jahrami et al., 2022). Moreover, exposure to blue light also seems to activate the ventrolateral and dorsolateral areas of the prefrontal cortex, which interferes with sleep by increasing alertness and working memory (Bano et al., 2021). Investigating the relationship between sleep deprivation and muscle glycogen, Skein et al. (2011) suggested the storage of muscle glycogen before exercise will be reduced after sleep deprivation, because the sleep deprivation prevents the replenishment of muscle glycogen after exercise, damages the energy supply for muscle fibre repair and contraction, and subsequently leads to a decline in endurance athletic performance. Watson and Brickson (2018) assessed the relationships between sleep quality, training load and emotional state in female soccer players over a year, and reported that reduced sleep time was positively associated with fatigue ($\beta = 0.15$, $p < 0.001$), mood ($\beta = 0.13$, $p < 0.001$), and stress ($\beta = 0.13$, $p < 0.001$). An experimental control study investigating the effects of 24 h of sleep deprivation on youth soccer skills showed that athletes in the sleep deprivation condition exhibited higher levels of subjective sleepiness and distraction, with impaired athletic performance on seven soccer skills tests (Pallesen et al., 2017).

In summary, previous studies have examined individual factors categorized into multiple aspects, each of which is based on different intermediate variables to explore the effects of MPD on athletic performance. Prolonged use of electronic devices has been proven to be a behavior that requires high cognitive inhibition and sustained attention. When athletes use electronic devices, the cognitive performance will be impaired, including disrupt attention, concentration, memory, and executive function (Durand-Bush and DesClouds, 2018). It is well-documented that these cognitive deficits and increased cognitive demands for a prolonged period may impair decision-making performance and executive functions in athletes, which in turn may limit athletic performance (Van Cutsem et al., 2017; Fortes et al., 2019; Gantois et al., 2020). Therefore, the following aspects for expansion could be considered in future research: (1) Multiple individual factors, including mental toughness, personality disposition, coping style, attachment, and self-esteem, should be fully incorporated into research on MPD to examine the specific conditions under which MPD plays a restrictive role in athletic performance, facilitating a detailed exploration of the influence paths and corresponding intervention programs from different perspectives; (2) Based on the results of cross-sectional studies, longitudinal and long-term follow-up research should be conducted to examine the influence relation between the two in a more systematic and dynamic way; and (3) Targeted intervention experiments, including psychological intervention (Malinauskas and Malinauskiene, 2019), mindfulness training (Lan et al., 2018), educational intervention (Khoshgoftar et al., 2019) and web-based group intervention (Brouzos et al., 2024), could be designed and implemented to examine the withdrawal effects of different interventions on athletes with MPD.

2.2 Environmental factors

Research on the impacts of MPD on athletic performance through environmental factors is primarily based on the self-determination theory's perspective on individual needs (Deci and Ryan, 2013). This theory classifies basic human psychological needs into three categories: relationship needs, autonomy needs and competence needs (Deci and Ryan, 2013). In essence, the communication between athletes and the outside world is a process of need fulfillment. According to the theory of compensatory internet use, most athletes are mentally immature, making them less capable of emotional regulation and socialization (Kardefelt-Winther, 2014). Consequently, they may find it challenging to meet their needs in real-world situations. Huang et al. (2022) found that social communications tend to be neglected by individuals with MPD, resulting in less time for offline communication with friends and family. This negatively affects the social–emotional support system, leading to alexithymia and increased loneliness. As a result, they may resort to inappropriate ways to meet social needs. Furthermore, individuals with MPD also tend to disregard their surroundings and develop a dependence on the virtual world accessed through mobile phones, with the execution of daily physical activities being affected. In sports, athletes with MPD may be influenced by the aforementioned behaviors, leading to formation of poor interpersonal relationships and incorrect interaction patterns, which are detrimental to the development of CAR and also hinder athletic performance. Evidence suggested that the interpersonal conflict within a team and poor team training atmosphere can easily

develop through poor CAR, discouraging athletes from striving for excellence (Wachsmuth et al., 2018).

Moreover, burnout in athletes will correspondingly develop due to uncoordinated CAR, which will cause athletes to lose motivations to focus on training and competition (Isoard-Gautheur et al., 2016). In contrast, the 3Cs model proposed by Jowett and Cockerill (2003) suggested that the more satisfying the relationship between athletes and coaches is, the greater the quality of that relationship and the better athletic performance. According to the model of sports engagement, when establishing high-quality CAR, athletes will receive more informational, emotional, respectful, and instrumental support from coaches, which will help them meet sports needs, achieve a dynamic balance between them and the environment, and ultimately improve athletic performance. Therefore, athletes with MPD may not be able to build a harmonious CAR due to their own poor relationship building and communication skills, which in turn has a negative impact on athletic performance. For athletes with MPD, harmonious CAR is difficult to build and develop due to poor relationship building and poor communication skills, with a corresponding adverse impact on athletic performance.

The uses and gratifications theory posits that athletes use social media for a variety of needs, and mobile phones, as a "ritualized" medium, can be used to satisfy athletes' needs to pass time, socialize and entertain, which are easy habits to develop (Katz et al., 1973). In the highly digital context, the convenience, entertainment and social functions offered by mobile phones may become a "psychological refuge" for athletes, allowing them to fully immerse themselves in social media interactions. However, when moving from the online world to the real world, such athletes may find it difficult to adjust their control and execution abilities, which can adversely affect athletic performance. A randomized and cross-over investigation of the inhibitory control performance (including accuracy and response time) showed that the mental fatigue caused by smartphone social media use resulted in higher response time than the control group at 10 min ($p = 0.01$) and 30 min ($p = 0.01$) after the resistance exercise session, suggesting that performing a high cognitive demanding activity (e.g., MPD) before training may trigger impaired inhibitory control performance (Lima-Junior et al., 2024). This evidence is consistent with findings from a randomized and experimental research with parallel groups, which found that the acute effects associated with 30 min of social media use before training interfered with the improvement of inhibitory control performance in athletes (Fortes et al., 2022b). The self-presentation model of social anxiety can be used to explain how social media affects athletic performance, stating that athletes attempt to present an idealized self-image to the public through online interaction, and that athletes will maintain their own self-image through frequent interaction when they are concerned about what others' opinions are, or when the ideal impression is questioned (Schlenker and Leary, 1982). As a result, athletes easily fall into a state of distraction and anxiety, and have difficulty focusing on training and competition. This finding conforms with the cognitive resource allocation theory, which suggests that most psychological resources will be devoted to processing trivial and cumbersome information due to athletes' frequent interactions with social media, giving rise to an under-allocation of localized resources and ultimately impeding athletic performance (Kahneman, 1973).

In summary, athletes' access to mobile phones can be increased through environmental factors, which can interfere with normal physiological and psychological states, causing poor interpersonal relationships, triggering interpersonal conflicts, and so on. Furthermore, the likelihood of athletes suffering from MPD can raise due to poor social environments, thus leading them to satisfy the needs through the virtual world and making it difficult for limited psychological resources to be used effectively for training activities. Studies have indicated that athletes who interacted with social media for more than 30 min before training experience a decrease in decision-making performance ($p = 0.001$), and an increase in internal training load ($p = 0.001$) (Fortes et al., 2023). Therefore, coaches and relevant managers should encourage athletes to abstain from social media on smartphones, such as WhatsAPP, Facebook, and Instagram, for at least 2-h before their training sessions, and strictly control and limit the frequency and duration of mobile phone usage by athletes (Fortes et al., 2021). By improving the environmental conditions of training and competition venues, including locker rooms and training grounds, and regularly carrying out psychological counseling, it is effective to guide athletes in developing proper ways of using mobile phones, eliminating external interference, focusing on training and competition, and striving to realize their own value. In addition, the coaching level and quality of coaches also play a vital role in influencing the MPD of athletes. Gearity and Murray (2011) have argued that bad coaches may be at greater risk in a number of ways, such as the suppression of mental skills and distraction of athletes, and thus eventually divide the team. The external factors mentioned above can also exacerbate psychological burden and affect the training state of athletes, further increasing the risk of developing MPD. Therefore, coaches and managers should pay attention to their own behavioral norms and optimize the training environment to eliminate the impacts of potential triggers of MPD and ensure that athletes are in an optimal psychological state.

3 Neurobiological mechanisms of the effects of MPD on athletic performance

Research on the neurobiological mechanisms underlying the effects of MPD on athletic performance has focused primarily on the brain reward system (BRS), which involves the areas of brain responsible for reward and loss of impulse control (Liu et al., 2019). The BRS comprises primarily the lower part of the cerebral cortex (e.g., amygdala, hippocampus and ventral striatum) as well as cortical areas responsible for executive functions (e.g., the left prefrontal cortex, orbitofrontal cortex, anterior cingulate cortex and insula) (Morgenstern et al., 2013). The lower part of the cerebral cortex primarily mediates neural processes related to emotion, memory and reward, while the cortical areas responsible for executive functions are involved in cognitive processes such as behavioral regulation and decision-making, which play a significant role in the control and direction of movement. For instance, when athletes with MPD use mobile phones, the brain's reward pathways may be stimulated due to the stimulation of mobile phone content, while dopamine with neurotransmitters will be released by the ventral tegmental area. These dopamine molecules rapidly bind to dopaminergic receptors in the ventral striatum, enabling athletes with MPD to produce a sustainable sense of excitement and pleasure (Sharma et al., 2021). Moreover, the amygdala, as a key site

for emotional processing and memory formation, and the hippocampus, as an important structure for learning and memory, reinforce the association between MPD and pleasurable memory in athletes and thus form the conditioned reward effect for mobile phone usage.

Therefore, athletes with MPD may be addicted to mobile phones for short-term, high-intensity reward satisfaction from mobile phones, prompting the body to secrete large amounts of dopamine. Thus these dopamine molecules can further increase the degree of MPD and weaken athlete's driving force for delayed reward processes such as training and competition, which will result in reduced vision, attention, reactions, and ultimately cause serious impairment of athletic performance. According to the brain reward theory (Berridge and Robinson, 2016), as behavioral dependence deepens, the function of the cerebral cortex will also be adversely affected, with the decision-making and executive function of athletes being debilitated (Benarroch, 2019; Xiao et al., 2022). Evidence has suggested that the decision-making of athletes relies on the abilities of the central nervous system to process information and motor responses, and that athletes are often required to make quick decisions in multitasking sports scenarios to cope with complex environmental changes (Hughes and Dai, 2023). However, the negative effects of MPD on the central nervous system may lead to an attenuation of information processing and reaction capacity, which could further restrict decision-making, distraction and athletic performance (Encel et al., 2017; Fortes et al., 2019).

Neuroimaging studies of social behaviors have demonstrated that social media use recruits brain network regions, including the prefrontal cortex (PFC), dorsomedial PFC (DMPFC), ventromedial PFC (VMPFC), bilateral temporoparietal junction (TPJ), anterior temporal lobes (ATL), inferior frontal gyri (IFG), and posterior cingulate cortex/precuneus (PCC) (Wolf et al., 2010; Schurz et al., 2014). Among these, the PFC and VMPFC are responsible for attention, processing information, cognitive interference control and decision-making during physical effort (Franco-Alvarenga et al., 2019; Friehs et al., 2020). Prolonged problematic use of mobile phones may lead to physical and mental fatigue and impair internal training load, heart rate variability and cognitive interference control, thereby adversely affecting athletic performance (Fortes et al., 2022a). Finally, mobile phones also emit microwaves and high electromagnetic modulated radiation, which interferes with synaptic neurotransmitters (dopamine, endogenous opioids, etc.) in the BRS, resulting in disruptions to the functions of the nervous system, endocrine system and immune system, as well as to some unique structures of the organism, including the brain waves, the blood–brain barrier and the pineal gland (De La Puente et al., 2007; Sharma et al., 2021). Studies have demonstrated that behavioral dependence involves multiple neurotransmitter systems, among which dopamine seems to be the most dynamic because it intervenes to a greater or lesser measure on a neuronal reward circuit known as the mesolimbic dopaminergic system (De La Puente et al., 2007). The radiation from mobile phones may interfere with the dopaminergic neural circuits in the BRS by affecting the dopaminergic nerve conduction in the synaptic cleft. Therefore, the attention, emotion regulation and decision-making abilities of athletes may be impaired by this interference to some extent. In summary, MPD, which mainly affects the reward pathway in the BRS and emits microwave radiation, could cause dysfunction of brain regions in athletes, potentially restricting athletic performance.

4 Relevant theoretical models of effects of MPD on athletic performance

4.1 The social cognitive model of self-regulation

The social cognitive model of self-regulation suggested that self-regulation of athletes can be seen as a process of interaction between athletes (including behavior and cognition) and the environment (Figure 1). Self-regulation refers to self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals (Zimmerman, 2000). The process of self-regulation involves three phases: preparation, execution (or volitional control), and evaluation, each of which also includes some key attributes required for athletes to successfully master and execute sports skills, such as

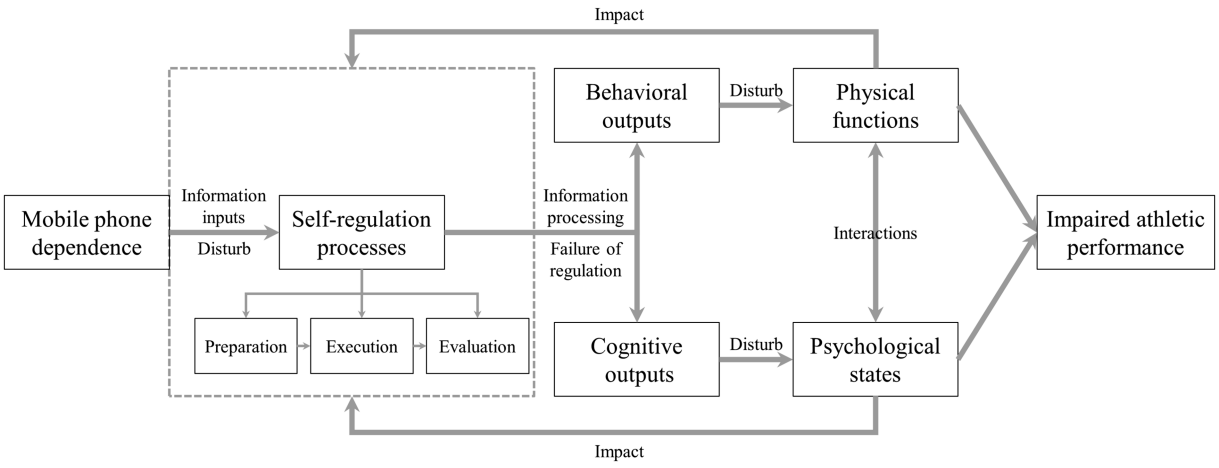

FIGURE 1
Social cognitive model of self-regulation.

self-efficacy, autonomous motivation, goal setting, and attentional capacity (Zimmerman, 2000). Among them, the preparation phase is the process by which the training or competition goals, plans, and strategies are set by the athletes; the execution phase involves the behavior of athletes that occurs during the implementation of an activity; and the evaluation phase refers to the self-observation and judgement of athletes at the end of activity (McCormick et al., 2019). The model pointed out that athletes may suffer from an imbalance in self-regulation due to the long-term effects of MPD, resulting in impairment of the preparation, execution, and evaluation phases, and further outputting disturbing signals to the behavior and cognition of athletes. Physical functions (physical capability, eyesight, sleep quality, etc) and psychological states (mood, engagement, resilience, etc.) are under the constant influence of these signals, with athletic performance being impaired. This finding is consistent with the self-regulation theory proposed by Köpetz et al. (2013), suggesting that MPD stems primarily from a failure of self-regulation, and that growing desires cannot be controlled due to the lack of self-regulation, making it difficult for athletes to eliminate MPD.

Studies have demonstrated that when frequently using mobile phones during training or competition, athletes will focus on irrelevant cues or outcomes (preparation phase), and such athletes cannot be able to fully engage in the execution of sports skills due to the adverse effects of this behavior such as distraction and a lack of self-preparation (execution phase), and the negative comments issued on social media will be checked by them (evaluation phase). Finally, it is easy for these athletes to make misattributions and non-adaptive judgments, leading to an imbalance in self-regulation (Durand-Bush and DesClouds, 2018). In a controlled trial examining the relationship between self-regulation and athletic performance in a 10-kilometre cycling time trial, it was found that athletes with suppressed levels of self-regulation had lower maximum heart rate, mean power outputs, and greater physical exertion when completing the race compared with normal athletes (Wagstaff, 2014). This suggests that the self-regulation disorder of athletes not only adversely affect their physiological function, but also limit athletic performance. In contrast, an intervention trial conducted on self-regulation strategies for college athletes has shown that after self-regulation strategies were applied to college athletes, such as reflection, time management, and cognitive restructuring, the stress levels of these athletes decreased significantly at different time periods, including pre to mid-intervention, post-intervention, and end-of-intervention, which contributed to athletic performance (Dubuc-Charbonneau and Durand-Bush, 2015). In summary, based on the perspective of the social cognitive model of self-regulation, MPD can be regarded as the result of a failure of self-regulation in athletes. Athletes with poor self-regulation are more susceptible to adverse influence from mobile phones, leading to self-regulation disorders and imbalance between the individual and the environment, which ultimately leads to a decline in athletic performance. In light of the negative influence of MPD on self-regulation in athletes, the self-regulation training, including mindfulness and attention control training, should be implemented by coaches and sports administrators, in a bid to help athletes resist negative external influence, and maintain a relative balance between athletes and their surroundings.

4.2 The integrative model of self-control

Self-control refers to the ability to maintain long-term goals by resisting inner desires and external temptations (Tangney et al., 2018). Athletes with weak self-control are less able to resist automated habitual actions, such as MPD, and tend to pursue immediate enjoyment, current desires, and novel experiences (Zhong et al., 2021). The integrated model of self-control suggested that self-control consists of control capacity, control motivation, control effort, high order goal (better athletic performance), behavioral dependence (MPD), conflict, and enactment constraints (Figure 2) (Kotabe and

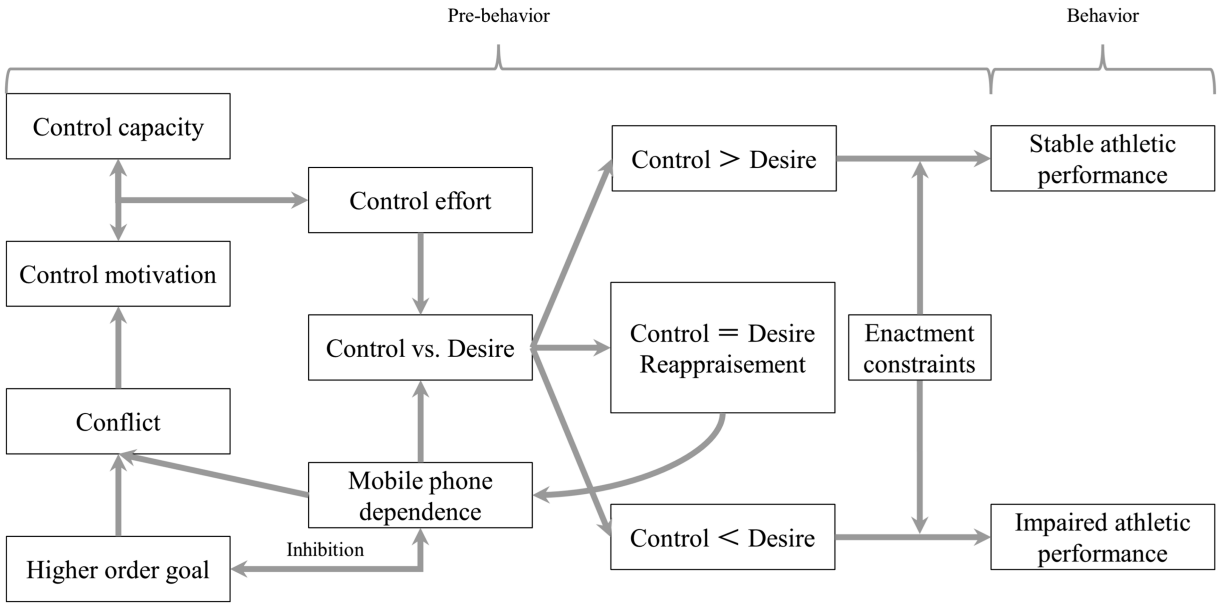

FIGURE 2
Integrative model of self-control.

Hofmann, 2015). Among them, the conflict will be created by the high order goal and MPD, by which the control capacity and control motivation work together to determine the degree of control effort to counteract the desire caused by MPD (Kotabe and Hofmann, 2015). The enactment constraints refer to the environmental factors that limit the behavior of athletes, such as coaches and training conditions. For athletes with normal mobile phone usage, whose degree of the control effort is greater than the desire for MPD, thus there is no behavioral dependence and the stable athletic performance is achieved. For athletes with MPD, however, desires override the control effort, which will lead to the failure of self-control, triggering a range of negative effects of MPD, including impaired athletic performance. Based on the perspective of this model, the control efforts of athletes can be seriously depleted by behavioral dependencies such as MPD. Faced with the pressure generated by training or competition, athletes with weak self-control are less able to suppress instant entertainment and social rewards (the desire to use mobile phones), making it difficult for them to perform at a normal level of athletic performance.

Self-control in athletes was associated with autonomous motivation (Jordalen et al., 2016, 2018). Athletes with higher levels of autonomous motivation and self-control tended to act in accordance with their values and needs, control their own behaviors in a more flexible manner, resist temptations (Deci and Ryan, 2013), and persist with training activities and long-term goals, in order to achieve delayed satisfaction with outstanding athletic performance (Tangney et al., 2018). For athletes with MPD, however, the failure of self-control makes it difficult to make rational judgments and maintain focus in training and competition, resulting in an inability to achieve optimal athletic performance. In contrast, the risk-buffering hypothesis states that self-control can be regarded as a protective mechanism against MPD, and athletes with greater self-control are able to effectively resist the temptation of mobile phones (Siegmann et al., 2018). For such athletes, the time spent interacting with mobile phones can be reasonably controlled, with more control resources applied to the execution of training and competition tasks, thus improving task focus and maintaining the stability of athletic performance (Niu et al., 2020; Zhong et al., 2021). Moreover, by following preset plans, athletes with greater self-control are able to concentrate on improving performance and attaining goals in intense sports, with athletic performance being enhanced in stressful environments (Englert, 2017). In summary, based on the integrative model of self-control, self-control can be seen as the key to moderating the effects of MPD on athletic performance. Sufficient control resources and motivations should be developed and allocated to various training tasks in a rational manner by athletes, so as to avoid crossing the "safety line" of mobile phone usage, to ensure that athletes are protected from the negative effects of excessive mobile phone usage, and to achieve optimal athletic performance.

5 Discussion

With the popularity of mobile electronic devices, people increasingly rely on mobile phones for information acquisition, social communication and entertainment in daily life. However, the likelihood of developing MPD will be increased by chronic problematic use of mobile phones. For athletes, due to long-term focus on training and competition, while facing greater pressure, such group are more inclined to regard mobile phones as "stress release device" and "psychological refuge". This implies that athletes are more susceptible to the detrimental effects of MPD, including distraction, mental fatigue, impaired decision-making, sleep disturbance, and poor social relationship, which can seriously hinder athletic performance (Stothart et al., 2015; Thun et al., 2015; Isoard-Gautheur et al., 2016; Romyn et al., 2016; Wachsmuth et al., 2018; Charest and Grandner, 2020; DesClouds and Durand-Bush, 2021; Fortes et al., 2021, 2022a,b, 2023; Alix-Fages et al., 2023; Lima-Junior et al., 2024). Therefore, early detection and effective intervention of MPD problems in athletes have become necessary and significant for improving their training and competition performance.

Based on individual factors, environmental factors, and relevant theoretical models, the present study examined the impacts of MPD on athletic performance, and explained the underlying mechanisms from a neurobiological perspective and relevant theories. First of all, grounded in the general stress theory, self-determination theory, compensatory internet use theory, and uses and gratifications theory, the restrictive effects of MPD on athletic performance through different pathways have been extensively explored. Furthermore, the mechanisms underlying the effects of MPD on athletic performance have been elucidated from the neurobiological perspective, and it has been suggested that the BRS may play a dominant and decisive role in activating the impacts of MPD on athletic performance. Finally, various models, notably the social-cognitive model of self-regulation and the integrated model of self-control, have been used to explain the effects of MPD on athletic performance. At present, although many valuable results have been obtained in this regard, there are still some problems that need to be addressed in future studies.

The effects of MPD on athletic performance and potential mediating and moderating variables that may exist within the process should be further explored and examined. The process of MPD affecting athletic performance is bound to be influenced by many mediating variables. Existing studies mostly focus on the individual level of athletes, including attentional resources (DesClouds and Durand-Bush, 2021), mental fatigue (Fortes et al., 2022a), and inhibitory control (Lima-Junior et al., 2024). While little consideration is given to the unique sociocultural factors of the sports environment, such as training atmosphere, coach style, and teammate relationships, which may facilitate or inhibit the impacts of MPD on athletic performance through moderating effects. Moreover, some positive psychological factors may have a protective role in the effects of MPD on athletic performance, including psychological resilience, coaching support, and sense of self-worth. For instance, athletes who have more positive evaluations of their own worth and ability may not be at risk of developing MPD, let alone gaining a sense of accomplishment from MPD. Instead, such athletes are more inclined to realize their self-worth through the pursuit of excellence, which helps reduce the likelihood of MPD. Therefore, it is necessary for future research to broaden the perspective, and take the relevant sociocultural and protective factors into consideration. And the potential limiting or protective roles of these factors in this process should be further examined, in order to interpret the relationship between MPD and athletic performance more comprehensively and accurately.

The relationships of MPD dynamically affecting athletic performance through a vertical research perspective should

be tracked. It is difficult to establish causal relationships between variables because the impacts of MPD on athletic performance from a vertical research perspective have rarely been examined by previous studies. As sports training is a chronic and dynamic process, athletes will experience many changes in terms of physical functions and psychological states during different periods, and the impacts of MPD on athletic performance vary considerably. In light of few vertical research results, vertical samples of athletes at different training periods and stages should be constructed to monitor the fluctuation relationship between MPD and athletic performance. Moreover, the evolution process, typical symptoms, development patterns, and harm of MPD in athletes at different training stages should be examined, explored and analyzed based on the qualitative research results. This will provide effective treatment programs for psychological counseling and experimental interventions targeted and requisite for athletes.

Based on brain reward mechanisms, research on the neurobiological mechanisms by which MPD affects athletic performance should be further expanded. At present, studies on the neurobiological mechanisms between the two mainly have focused mainly on brain regions linked to reward-activated pathways and the effects of microwave radiation on brain structures (De La Puente et al., 2007; Liu et al., 2019; Sharma et al., 2021), but the specific mechanisms by which MPD affects the structure and function of brain regions still need to be further refined. Evidence has indicated that MPD is similar to other types of behavioral dependence such as gambling, smoking, and shopping, that is, they are all associated with structural brain abnormalities (Xiao et al., 2022). In light of the current understanding of the neurobiological mechanisms underlying the effects of MPD on athletic performance, the following interventions could be considered in future research: (1) The cognitive-behavioral interventions could be adopted to help athletes change their thinking patterns and behaviors, and personalize strategies to resist excessive mobile phone usage; (2) The biofeedback training could be employed to strengthen the self-control and attention management abilities of athletes, including eye movement techniques, brain waves, heart rate variability and other indicators, allowing athletes to establish the correct pattern of brain activity; (3) Based on functional magnetic resonance imaging, the relevant changes in brain reward regions of athletes during activation could be identified to monitor the modulation of the dopamine conduction system; and (4) The volume and intensity of training should be scientifically regulated, and high-intensity interval training could be applied to promote the release of endorphins in the brain, thus replacing the rapid reward pathway caused by MPD.

Based on empirical and intervention research combined with interdisciplinary perspectives, the theoretical model and framework of the impacts of MPD on athletic performance should be validated, developed and enriched. The restrictive effects of MPD on athletic performance have been explained by the social cognitive model of self-regulation and the integrative model of self-control from different disciplinary perspectives (Zimmerman, 2000; Kotabe and Hofmann, 2015). However, the factors involved in these models are relatively simple, focusing only on self-regulation and self-control at the individual level, and ignoring the influence of external factors in the social environment. Therefore, the scientificity and effectiveness of existing theoretical models should be examined by designing more rigorous randomized controlled trials and intervention programs, on the basis of which these models can be further developed and their predictive and explanatory credibility improved. In addition, the existing models are mainly derived from the filed of psychology, which suggests that the relevant theories and methods regarding neuroscience, cognitive science, social science and other fields should be absorbed, constructing an interdisciplinary and comprehensive model combined with the results of intervention experiments, with a view to provide theoretical support and guidance for improving the symptoms of MPD in athletes, returning to normal life, and restoring a healthy state of mind and body.

Author contributions

ZM: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization. YZ: Writing – original draft, Visualization, Investigation, Conceptualization. QF: Writing – review & editing, Visualization, Resources, Conceptualization. SUL: Writing – review & editing, Visualization, Methodology, Conceptualization. SIL: Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, 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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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Zhen Leo Yang,
KU Leuven, Belgium
Ana Sofia Barros Soares,
University of Porto, Portugal

*CORRESPONDENCE
Antonio Castillo-Paredes
✉ acastillop85@gmail.com

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Life satisfaction among Spanish children and adolescents participating in Physical Education

Santiago Gómez-Paniagua[1], Antonio Castillo-Paredes[2]*, Carmen Galán-Arroyo[3] and Jorge Rojo-Ramos[1]

[1]Faculty of Sport Sciences, BioĒrgon Research Group, University of Extremadura, Cáceres, Spain, [2]Grupo AFySE, Investigación en Actividad Física y Salud Escolar, Escuela de Pedagogía en Educación Física, Facultad de Educación, Universidad de Las Américas, Santiago, Chile, [3]Faculty of Sport Science, Physical and Health Literacy and Health-Related Quality of Life (PHYQoL), University of Extremadura, Cáceres, Spain

Life satisfaction has been determined as a cognitive indicator of subjective wellbeing, a term that acquires vital relevance during adolescence as a protective factor against numerous psychological, mental and social disorders. Therefore, the objectives of this study are: (1) to evaluate differences in life satisfaction as a function of gender and school environment in Spanish children and adolescents; and (2) examine the possible associations between life satisfaction and age and/or body mass index (BMI) of the student body. For this purpose, a cross-sectional study was carried out with 723 students (aged 6 to 18 years) in which the "Satisfaction with life Scale" was applied, consisting of 5 items that measure self-perception of life satisfaction. Nonparametric statistics (Mann–Whitney *U* test) were used to explore differences in scores according to sex and school environment, in addition to Spearman's Rho test to identify associations between scale scores and students' age and BMI. Significant differences were obtained in terms of sex in favor of the male gender, and between the two environments of the centers in favor of the rural ones. In addition, the two variables explored (age and BMI) showed significant inverse associations with life satisfaction levels. Therefore, educational interventions and policies must take this information into account to design and develop actions aimed at improving this cognitive factor.

KEYWORDS

life satisfaction, adolescent, children, Physical Education, students, school

1 Introduction

Over time in scientific literature, three concepts have been used interchangeably to define an individual's overall assessment of their life: happiness, life satisfaction (LS) and subjective well-being (SWB) (1). In this sense, Diener (2) pointed out that LS, as a mental indicator of SBW, can be understood as a cognitive process and judgment of one's own satisfaction with life experience (3), or, in the words of Núñez (4), LS can be framed as a cognitive judgment about the quality of one's own life in which the criteria for judgment are specific to each individual. Vennhoven (5) also made his contribution around the concept of LS, defining this construct as the degree to which the person positively evaluates the overall quality of their as

a whole, being influenced by 4 different dimensions: overall LS, satisfaction with housing, satisfaction with finances, and satisfaction with social contacts. Conversely, a person's sense of well-being is characterized by both feeling good and performing well; it also includes achieving one's potential, taking charge of one's life, having a sense of purpose, and being in happy and contented relationships (6). Within this description, it is important to highlight the multidimensional model of SWB developed by Diener et al. (7) and formed by four components: (1) global LS; (2) positive affect; (3) negative affect; and (4) satisfaction with specific domains of life.

In this context, different studies have pointed out several changes in the factors that determine well-being, therefore, the levels of LS have been characterized throughout the life cycle of different populations (8, 9). In particular, LS ratings show a U-shaped pattern in most of the research, with a reduction in LS during adolescence and early-middle adulthood, increasing drastically in older age (10). This U-shape has been defined as a paradox by numerous research teams, as some conditioning factors (such as monetary income) improve during the age range in which a worse level of LS is identified, while other indicators (such as general health) experience lower levels when the LS trend reverses at the end of the life cycle (11).

Adolescence has been identified as a stage of mental health risk in the life cycle (12), mainly due to the numerous physiological and psychological changes, in addition to the frequent disruptions in the social environment. Blakemore (13) defines it as the period of life between puberty and adult independence, which requires both individual development and cultural norms. During this particular stage, biological, psychological, cognitive and social changes may affect the LS assessment process, and self-concept may be considered an indicator of how adolescents cope with these changes in relation to LS (14). However, to the best of the authors' knowledge, there is no scientific evidence that evaluates LS in early adolescence and how it evolves during the later years of early adulthood, as there are only longitudinal studies focusing on periods within the adolescent stage (15) or cross-sectional research focused on adolescents (16). The findings imply that the apparent decrease in SWB around the middle of adolescence may, in fact, start earlier and last longer throughout adolescence (15, 16). However, because most research have not yet looked at big age spans in adolescence or the transition between adolescence and adulthood, it is still unclear when exactly significant losses in LS begin. Following this line of thought, the school environment seems to have a great influence on the SL of children and adolescents (17). Academic results seem to be related to higher LS, with the practice of physical activity (PA) being the most important mediator for improving the mental health of students (18). Consequently, the Physical Education (PE) classroom becomes a fundamental context, since those students who show greater satisfaction with the subject experience greater intrinsic motivation (19), thus improving their academic results as well as their PA levels (20).

Similarly, numerous factors have been identified as relevant when analyzing the SL of children and adolescents. In this regard, differences have been found in terms of gender when analyzing this variable, although the results of the different studies differed. While several of them showed higher LS levels in the male gender (21), other studies, on the other hand, report no real differences in LS levels when sex is introduced as a variable for analysis (22). Likewise, the environment in which individuals reside plays a crucial role in their LS levels, although it is not a subject of widespread study among the scientific community. However, over the last few years, this topic has been gaining increasing interest and has given rise to a body of literature with diverse findings in various contexts (23). For example, Swami & Todd compared LS levels in Malaysian adults residing in rural and urban areas, with those individuals from rural environments exhibiting higher levels of LS (24). This trend has also been observed in migrants from rural to urban areas, who expressed a lower LS a few months after their relocation (25). Despite this, there is little literature that replicates these types of studies in adolescents and children (26, 27). On the other hand, overweight in children and adolescents is related to the development of a wide range of different pathologies, such as cardiovascular diseases or sleep problems (28). In addition, the consequences and complications of these diseases have a negative impact on the SWB of children and adolescents, reducing their LS (29, 30). In addition, psychological problems such as anxiety and depression can be considered as another factor to take into account in terms of reduced SWB (31), as well as the social problems they may suffer because of this status, since previous research has pointed to overweight schoolchildren as targets of behaviors such as bullying or marginalization (32).

Considering the enormous positive impact that LS has on the psychosocial development of children and adolescents, such as combating mental problems caused by stress or favoring situations of exploration of their environment (33, 34); and since LS is a concept with a higher reliability and stability compared to mood states when assessing SWB (35), this study focuses on LS with life as a cognitive indicator of SWB. Therefore, the aim of this research is to evaluate the levels of LS of PE students in primary and secondary education (from 6 to 18 years old) in a region in southwestern Spain (Extremadura), analyzing the possible influences of gender and environment of residence. In the same way, we also intend to explore the possible associations between LS and the variables age and BMI in this population. In this sense, and after reviewing the most relevant scientific literature on the subject, it is hypothesized that male students and those residing in rural areas will show higher levels of LS compared to their female and urban peers. Likewise, negative associations between LS and student age and BMI are predicted throughout the age period studied.

2 Materials and methods

2.1 Participants

This research followed a descriptive cross-sectional design. The sample size was selected following the non-probabilistic sampling method based on convenience sampling (36), since the purpose was to collect as many students as possible. Of the total sample (N = 723), 50.62% were boys and 49.38% were girls, so it can be considered that the sample was balanced in terms of gender. Regarding the location of the center, 47.99% studied in rural schools and 52.01% in urban schools. Rural schools were considered to be those located in towns with less than 20,000 inhabitants and urban schools those with more than 20,000 inhabitants, following the criteria established by regional public organization (https://www.dip-caceres.es/). The mean age was 13.08 years ($SD = 1.78$) and the mean BMI was 22.70 (kilograms of weight divided by height in meters squared) ($SD = 2.39$).

In order to participate in the study, two inclusion criteria were established: (a) To have the informed consent of the parents/legal guardians; (b) To be a student of the subject of Physical Education in Extremadura public educational institutions of Primary (between 6 and 12 years of age) or Secondary-Baccalaureate (between 12 and 18 years of age) education. Table 1 shows the sociodemographic characterization of the sample.

2.2 Procedure

Firstly, the contact details of the schools providing Primary Education (6–12 years), Compulsory Secondary Education (12–16 years) and/or Baccalaureate (16–18 years) in Extremadura were obtained from the directory of Extremadura public schools. This register was provided by the Department of Education and Employment of the Regional Government of Extremadura.

Next, to establish contact with the Physical Education teachers of the schools included in the list, an e-mail was sent to the schools containing information about the study: (1) objectives; (2) model of the instrument; and (3) informed consent to be signed by the parents/legal guardians. All teachers who wished to participate in the study had to respond to the e-mail to make an appointment with a member of the research team who would supervise the completion of the questionnaires, in addition to obtaining the informed consent of the parents/legal guardians.

Similarly, when the researcher went to the center to administer the questionnaire through Google Forms with Tablets, he first checked that all the students had parental informed consent. In addition, before answering the questions, they were read aloud by the researcher to ensure that there were no doubts about the items and the instrument. On the other hand, the reasons for deciding to complete the questionnaire online were organizational and economic, so that all the data were collected in the database, facilitating their processing, and no money was invested in replicating the instrument. The questionnaires were administered to the participating students, whose data were collected anonymously, during the first academic term of the year 2022. The students took an average of 10 min to complete the instrument. The study was conducted in accordance with the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of the EDUCA platform for excellence in educational research (approval code: 42022).

TABLE 1 Sample characterization ($N = 723$).

Variable	Categories	*N*	%
Sex	Boy	366	50.6
	Girl	357	49.4
	Primary Education	267	36.9
	Secondary Education	441	61
	Baccalaureate	15	2.1
Center environment	Rural	347	48
	Urban	376	52

Variable	*M*	*SD*
Age	13.08	1.78
Weight	57.90	15.13
Height	1.57	0.14
BMI	22.70	2.39

N, number; %, percentage; SD, standard deviation; M, mean.

2.3 Instruments

First, sociodemographic data were collected through a questionnaire of own elaboration in which six questions were included to determine the characterization of the sample: sex, age, height, weight, grade, and location of the center.

On the other hand, the Spanish version of the "Satisfaction With Life Scale" (SWLS) (37) was applied in order to analyze the students' self-perception of their LS. The SWLS aims to assess the learner's overall judgment of their LS as a cognitive indicator of their SWB (3). This instrument is designed on a 5-point Likert-type response scale with the following values: (1) strongly disagree; (2) disagree; (3) indifferent; (4) agree; and (5) strongly agree; to offer the respondent a variety of possible answers. Since the five items are all oriented in a positive manner, adding the five answers will yield the scale's total score. Due to the unifactorial structure of the instrument, it showed good psychometric properties in children and adolescents (Cronbach's alpha = 0.84) (37).

2.4 Statistical analysis

Initially, the assumption of normality was tested using the Kolmogorov–Smirnov test to analyze the distribution of the data. In this case $p < 0.05$ was obtained, therefore it was confirmed that the assumption was not fulfilled and that the most appropriate tests were non-parametric.

The Mann Whitney U test was used to analyze the differences in the scores in each of the SWLS items and as well as in their total score as a function of the sex or demographic location of the participants. A significance value was set for $p < 0.05$. Hedges' g was used to determine the effect size of sex or demographic location for each SWLS item. Values less than 0.20 indicate no effect, values between 0.21 and 0.49 indicate a small effect, values between 0.50 and 0.79 indicate a moderate effect, and finally, values greater than 0.80 indicate a strong effect (38).

To determine the degree of relationship between LS and age or BMI, Spearman's Rho test was used. For the interpretation of this statistic, we took into account the ranges established by Mondragón Barrera (39) who determined that coefficients between 0.01 and 0.10 determined the existence of a low correlation, values between 0.11 and 0.50 implied a medium degree of correlation, from 0.51 to 0.75 a strong correlation, from 0.76 to 0.90 a high correlation and above 0.91 the correlation was perfect.

Finally, the Cronbach's Alpha and McDonald's Omega coefficients were used to evaluate the reliability of the psychometric scales based on their internal consistency. To interpret the values reported, those established by Nunnally and Bernstein (40) were chosen, which indicated that values below 0.70 would correspond to low reliability,

values between 0.71 and 0.90 would correspond to satisfactory reliability, and values above 0.91 would correspond to appropiate reliability.

Apart from that, the data collected in the questionnaires were processed with the statistical analysis software Statical Package of Social Science (SPSS) version 23 for Media Access Control (MAC). Likewise, the information on the variables analyzed was organized in tables indicating the total number (N) and percentage (%) in the case of the sociodemographic data, and the mean (*M*) and standard deviation (*SD*) for the scores obtained in each item and in the overall SWLS.

3 Results

Table 2 shows the descriptive data (from the mean and standard deviation) and the differences for each of the items that make up the SWLS as a function of sex and center location.

If the sex variable is observed, we can see that in all the items the boys obtained a higher score than the girls, with statistical significance in all of them as well as in the overall score. As for effect size, all differences could be defined as small except for item 4 ($g = 0.14$) In addition, regarding the environment variable, it can be observed that students whose educational center was located in a rural area showed greater LS than those belonging to urban areas, with a significant difference in items one, three and four, as well as in the final score. However, only item 4 ($g = 0.26$) and the final scale score ($g = 0.42$) reached a small effect size.

Table 3 shows the correlation between the different items of the SWLS and the variables age and BMI, using Spearman's Rho test for its analysis.

Regarding the data obtained for the age variable, inverse, significant and medium associations were found with items 2, 3 and 4 and with the global questionnaire score. Likewise, BMI exhibited significant inverse correlations when associated with items 2, 3 and 4, in addition to the overall scale score. However, only item 2 was characterized by a medium correlation, while the correlation for the rest of the items was low.

Finally, the internal consistency of the instrument was calculated using Cronbach's Alpha ($\alpha = 0.82$) and McDonald's Omega ($\omega = 0.81$) statistics. These values can be considered satisfactory following the recommendations of Nunnally and Bernstein (40).

4 Discussion

The objective of this research was to describe the levels of LS, as a cognitive indicator of SWB, of children and adolescents in the region of Extremadura, including for the first time in a single study a wide age range. Similarly, and after reviewing the expert bibliography on the subject, the possible influences of both gender and the school environment on these levels were analyzed. Finally, the possible correlations between scale scores and participants' age and BMI were explored.

Regarding the gender variable, statistically significant differences were found in all items and in the overall score of the questionnaire in favor of boys. These results are consistent with previous findings by other researchers, for example Goldbeck and coworkers (41) studied the various domains of SWB in German adolescents, extracting significantly higher LS levels in the male gender. In the Spanish context, Fraguela Vale et al. (42) conducted a study with more than a thousand post-compulsory education students (16 to 18 years old),

TABLE 2 Scores and differences obtained according to sex and center location of the items of the SWLS.

Items	Sex				Environment			
	Boy	Girl			Rural	Urban		
	M (*SD*)	*M* (*SD*)	*p*	*g*	*M* (*SD*)	*M* (*SD*)	*p*	*g*
1. In most ways my life is close to my ideal	3.82 (1.06)	3.65 (0.97)	<0.01*	0.17	3.84 (1.00)	3.64 (1.03)	<0.01*	0.20
2. The conditions of my life are excellent	4.35 (0.84)	4.15 (0.96)	<0.01*	0.22	4.29 (0.85)	4.22 (0.95)	0.57	0.08
3. I am satisfied with my life	4.46 (0.90)	4.27 (0.92)	<0.01*	0.21	4.44 (0.85)	4.30 (0.97)	0.04*	0.15
4. So far I have gotten the important things I want in life	4.25 (0.95)	4.12 (0.94)	0.02*	0.14	4.31 (0.87)	4.07 (1.00)	<0.01*	0.26
5 If I could live my life over, I would change almost nothing	3.78 (1.27)	3.53 (1.23)	<0.01*	0.20	3.66 (1.25)	3.65 (1.27)	0.99	0.01
SWLSS	4.10 (0.61)	3.89 (0.54)	<0.01*	0.36	4.12 (0.50)	3.88 (0.63)	0.03*	0.42

p is significant < 0.05*. *M*, mean value; SD, standard deviation. Each score obtained is based on a Likert scale (1–5): 1 "Strongly disagree," 2 "Disagree," 3 "Indifferent," 4 "Agree," 5 "Strongly agree."

TABLE 3 Correlation between SWLSS items and age and/or BMI.

Items	Age ρ (p)	BMI ρ (p)
Item 1	−0.04 (0.25)	−0.04 (0.22)
Item 2	−0.14 (<0.01*)	−0.12 (<0.01*)
Item 3	−0.16 (<0.01*)	−0.09 (0.01*)
Item 4	−0.17 (<0.01*)	−0.09 (0.02*)
Item 5	−0.05 (0.17)	−0.05 (0.18)
SWLSS	−0.13 (<0.01*)	−0.10 (0.01*)

p is significant < 0.05*. Each score obtained is based on a Likert scale (1–5): 1 "Strongly disagree," 2 "Disagree," 3 "Indifferent," 4 "Agree," 5 "Strongly agree."

belonging to both public and private schools, identifying higher levels of LS in male students. Similarly, Reina Flores et al. (43) obtained the same relationship in a sample of 2,400 adolescents aged 12 to 17 years in southern Spain. These differences may occur, as experts point out, to girls experiencing higher levels of social support but tending to disclose negative feelings more frequently than men in everyday life (14), so that LS levels are equalized over the years. However, Aznar et al. (44) found favorable differences in favor of females in a large sample of adolescents in compulsory secondary education. In addition, there is another group of studies in which these differences in LS could not be appreciated when the gender variable was introduced (45, 46), even in Spanish-speaking populations in South American countries (47). This issue has already been discussed by previous research (48), which pointed out that the differences found in LS were not due to gender, but to economic status. Similarly, some researchers noted that despite the disparity in social opportunities, our society has made great efforts to distribute resources equally between men and women (49). This may have contributed to men and women's balanced perceptions of LS (50).

Also, the environment in which a person resides and studies seems to have a great influence on an individual's LS. To the authors' knowledge, there is a paucity of scientific literature analyzing differences in SL according to the environment of residence in the adolescent population. In the present study, differences were found in rural students' favor in three of the five items that make up the scale, as well as in their overall score. These findings follow the line of research conducted by Marquez and Long (51), in which they evaluated the levels of LS in 15-year-old adolescents in 46 countries, finding that in general levels those belonging to rural communities showed better levels despite the decrease experienced during the last few years. Likewise, Abreu and collaborators (26) pointed out the existing differences in LS in 757 adolescents from the north of Brazil, being the schoolchildren from urban areas those with better levels of LS. In this context, research conducted in India that explored the LS of university students found similar results, justifying the worse scores of urban students due to a frenetic lifestyle and the accumulation of stress (23). On the contrary, Li et al. (52) tried to explore the determinants of LS and its differences according to the environment of residence in Chinese adults, pointing to urban communities as those more satisfied with their lives. Additionally, they claimed that ancestor worship, financial stress, depressive symptoms, and ease of access to healthcare were all strongly associated with LS. Additional research also found differences in cognitive aspects between rural and urban areas. For example, prevalence of depression is higher in rural than in urban adults (53); likewise, SWB is more common in rural than in urban chronic patients (54). However, another study conducted on about thirty-five thousand Chinese adults reported no difference in assessing the residence environment as a mediator of LS (55). This is consistent with research in Spanish schoolchildren, where equality in LS scores was observed between the two environments (47). However, international researches obtain the same conclusion, the heterogeneity of the results indicate that the relationship between environment and LS varies between countries and regions (51), although earlier studies (56, 57) found some commonalities in determinants of teenage LS across nations and different factors. Thus, future studies should investigate the potential causes of these trends in teenage SWB and mental health outcomes, taking into account regional and national variations.

Regarding age, this research found a significant inverse association in three of the five items of the questionnaire as well as in its overall score. This question has been advocated by much of the scientific research in the field of SL, which advocates that SL declines in late adolescence and early adulthood, a decline that continues into middle age (8, 58). This trend was also seen by Orben et al. (59), who analyzed the evolution of LS from 10 to 24 years of age in both German and UK populations, finding evident signs of a decrease in this cognitive indicator of SWB during adolescence. Similarly, Goldbeck et al. (41) found a significant negative association between age and perceived LS in a sample of 1,274 German adolescents aged 11–16 years. Also, Aymerich et al. (60) showed that this decreasing trend began at 11 years of age when analyzing 600 Spanish adolescents, emphasizing the importance of psychological/affective care in the pre-adolescent and adolescent stages of life. Within this context, the possible causes underlying this decline in LS include shifting assessments of LS questions and rising social, financial, professional, or familial demands (61). Therefore, it can be emphasized that the results of the present study coincide with those presented in several studies of cross-sectional design (62), as well as those of longitudinal design (63), carried out with samples of adolescents. Experts explain this pattern by speculating that either the drop in LS scores during adolescence is a result of specific processes or that living situations during this time are becoming worse, such as increasing social insecurity, autonomy, or uncertainty (64). Though mental health and LS are not the same thing, adolescents suffer from mental illnesses like anxiety and depression and other aspects of SWB declines (65).

BMI has also been incorporated into the study as an influential variable in the LS of the participants, finding a significant and inverse correlation in 3 of the 5 items of the questionnaire as well as in their final score. These results are in line with those found by Baile et al. (66) who evaluated the possible influence of BMI on LS in 1200 Spanish adolescents, reporting lower levels of LS as student BMI increased. However, the CASPIAN-III study (67) found no relationship between BMI and LS in more than 5,000 Iranian students aged 10–18 years. Similarly, Tabak et al. (68) observed that adolescents with obesity reported lower levels of LS compared to their healthy peers, however the findings pointed to self-perceived body image as a mediator of LS and not BMI. Therefore, the studies developed in the Spanish context differ from those developed internationally. This could be because, despite the interpretative logic surrounding health's implications that low weight should harm a person's overall development, low weight is seen as a positive value in Spanish society, generating recognition and

reinforcement that can mitigate the detrimental effects on health and have a positive impact on the subjective variables of quality of life and LS (69).

4.1 Practical implications

This research has shown the relevance of gender and school environment on students' LS levels. Therefore, all interventions and programs proposed in a school context should consider these findings in order to improve this cognitive component of SWB. In this sense, implementing tasks or goals that are difficult to achieve will not only produce frustration in the students, but may also mentally affect this population, which is at a critical stage for their personal development. Following this current of thought, the teaching-learning process should be based on achievable goals for the students, being adapted according to the characteristics of the group, involving all educational agents to foster a positive, harmonious and motivating development environment. Interventions should also pay special attention to other psychological factors such as body image, the development of social relationships, the acceptance of low weight as a positive element or general mental health, as they have an important influence on LS, and therefore, on SWB.

4.2 Limitations and futures lines of research

The present investigation has certain limitations. Due to its cross-sectional design, the results should be interpreted with caution since cause-effect relationships cannot be developed. Also, the participants belonged to the same region of southeastern Spain, so there are several sociocultural factors that could affect the scale responses. In addition, only quantitative methods were used, although qualitative methodology could generate relevant information regarding other mediators of SWB.

As for future lines of research, it is proposed to conduct a longitudinal study in populations of wide age ranges in order to identify environmental factors that may decrease LS levels in this population, as well as to determine those critical periods in which more attention should be paid to the students. It would also be interesting to extend this study to other Spanish communities, which would make it possible to detect possible differences and adapt educational interventions and policies to each context. Finally, it would be interesting to adapt the questionnaire so that educational agents could indicate what they believe to be the LS levels of their students, so that the differences between the results provided by students and teachers could be reduced by means of intervention programs.

5 Conclusion

Significant differences were found in terms of student gender in all the items that made up the LS measurement scale as well as in the final score of the same, being the male gender the one with the best scores. Students in rural settings generally showed higher LS compared to their peers in urban settings. Similarly, both BMI and age showed a significant and inverse association with LS in students from schools in the region of Extremadura (Spain). These findings show how students' SL can be mediated by different variables both intrinsic to the learners and extrinsic to them. Therefore, interventions should be designed, adapted and developed in different settings with specific objectives, so that the learner perceives higher levels of SL after the achievement of the interventions.

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 study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the EDUCA platform for excellence in educational research (approval code: 42022). 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

SG-P: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. AC-P: Funding acquisition, Investigation, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing, Validation. CG-A: Funding acquisition, Investigation, Resources, Supervision, Visualization, Writing – original draft, Writing – review & editing. JR-R: Investigation, Methodology, Project administration, Resources, Software, Supervision, 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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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Fernando Jorge Santos,
Instituto Politecnico de Setubal (IPS), Portugal
Daniel Cabral,
Virginia Tech Carilion, United States

*CORRESPONDENCE
Renyang Liu
✉ 18758094075@139.com

†These authors have contributed equally to this work

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Effects of physical activity on depression, anxiety, and stress in college students: the chain-based mediating role of psychological resilience and coping styles

Ming Liu[1†], Huanju Liu[2†], Zhuzhu Qin[3†], Yining Tao[4], Wan Ye[5] and Renyang Liu[6*]

[1]Department of Public Physical and Art Education, Zhejiang University, Hangzhou, Zhejiang, China, [2]Center for Genetic Medicine, The Fourth Affiliated Hospital, Zhejiang University School of Medicine, Hangzhou, Zhejiang, China, [3]School of Nursing, Fujian University of Traditional Chinese Medicine, Fuzhou, Fujian, China, [4]Department of Global Public Health, Karolinska Institutet, Stockholm, Sweden, [5]Department of Nursing, Xiamen Medical College, Xiamen, Fujian, China, [6]Emergency and Critical Care Center, Intensive Care Unit, Zhejiang Provincial People's Hospital (Affiliated People's Hospital), Hangzhou Medical College, Hangzhou, Zhejiang, China

Background: Physical activity can alleviate negative emotions in college students by enhancing mood and cognitive functions. Yet, the mechanisms underlying these benefits remain unclear.

Purpose: This study examines the association between physical activity and negative emotions—specifically, depression, anxiety, and stress—in college students. Additionally, we explore the mediating effects of psychological resilience and coping styles to offer theoretical and practical insights for mitigating students' negative emotions.

Methods: Using a stratified random sampling approach, a total of 1,380 college students, from five universities in Hangzhou, Nanjing, and Wenzhou, were included in the analysis. The survey instruments included the Physical Activity Rating Scale, Connor-Davidson Resilience Scale, Simple Coping Style Scale, and Depression-Anxiety Stress Scale. The data were statistically analyzed using multivariate methods with IBM SPSS 25.0 and the PROCESS V3.3 plug-in.

Results: (1) College students engage in a low level of physical activity, with male students participating significantly more than female students ($p < 0.001$). (2) Physical activity was significantly positively correlated with psychological resilience and positive coping styles ($t = 9.126$, $p < 0.001$; $t = 23.087$, $p < 0.001$) and overall negative correlated with negative emotions in college students ($t = -3.601$, $p < 0.001$). (3) Psychological resilience and positive coping styles were found to play a chain mediating role between physical activity and negative emotions. The mediation effect consists of two paths: physical activity → psychological resilience → negative emotions (effect value: −0.0324), and physical activity → psychological resilience → positive coping → negative emotions (effect value: −0.0099). (4) Female students demonstrated higher levels of positive coping ($p < 0.001$), while male students exhibited more negative emotions ($p < 0.001$).

Conclusion: Our study identifies a significant indirect link, mediated by psychological resilience and positive coping styles, between physical activity and the reduction of negative emotions. Targeted interventions addressing gender differences, such as offering special courses and providing specialized exercise programs and emotional management strategies, can enhance psychological

resilience and positive coping mechanisms. Consequently, these measures can alleviate the adverse effects of negative emotions. Our findings have broader implications for both research and practical interventions in promoting mental health among college students.

KEYWORDS

physical activity, negative emotions, psychological resilience, coping styles, chain mediation

Introduction

Negative emotions, a common and serious problem among college students, can affect their mental and physical health, academic performance, and quality of life (Yousif et al., 2022). The sources of negative emotions in college students are varied and complex, including academic pressure, competition, social stress, emotional issues, and financial strain (Karyotaki et al., 2020). These stressors can trigger negative emotions and impair cognitive functions, such as attention, memory, and decision-making (Gong et al., 2023; Wen et al., 2023). A national Healthy Minds Study found that over 60% of students were dealing with at least one mental health issue, such as symptoms of depression and self-injury (Lipson et al., 2022). This study also revealed significant disparities across the US, with these issues being particularly prevalent among racial/ethnic minority students. Further studies have underscored a positive correlation between pressure and depression among college students, with the prevalence of depression among Chinese college students reported to be as high as 28.4% (Gao et al., 2020). Long-term exposure to negative emotions can not only lead to mental disorders but also physical problems such as inflammation and cardiovascular diseases (Schneiderman et al., 2005). Therefore, the mental health of college students has become a social issue warranting attention from all sectors of society.

One of the factors that can influence college students' mental health is physical activity. Insufficient physical activity among college students can compromise bone and functional health, potentially leading to obesity, vision loss, and serious psychological issues (Brown et al., 2024). Physical activity can confer numerous benefits to both the body and mind, including mood enhancement, improved self-confidence, alleviation of mild depression and anxiety symptoms, better concentration, enhanced learning engagement, and memory boost (Malm et al., 2019; Li and Guo, 2023). Moreover, physical activity can also reduce the level of cortisol, a stress hormone, and improve the immune system (Gerber et al., 2020; Xu et al., 2021). Physical activity serves as a beneficial coping mechanism for negative emotions, especially during the quarantine period caused by the COVID-19 pandemic (Xu and Yang, 2023). Some studies have demonstrated a negative correlation between moderate physical activity and negative emotions in college students (Aperocho et al., 2021; Tao et al., 2023). In addition, physical activity can also improve the academic performance of college students by reducing their academic anxiety (Fricke et al., 2017).

However, the relationship between physical activity and negative emotions in college students may not be as straightforward or simple as it appears. There may be underlying mechanisms that mediate or moderate this relationship. For example, some studies have suggested that psychological resilience and coping styles are important factors that affect how college students deal with negative emotions (Freire et al., 2020; Wu et al., 2020). Psychological resilience is characterized as the ability to rebound from substantial stressors, including familial and relational challenges, serious health issues, and occupational or financial difficulties. In the face of these stressors, coping styles are the strategies employed to manage and adapt to such adversity. Given this, it is conceivable that physical activity may exert an indirect influence on negative emotions by modulating psychological resilience factors and coping styles. This underscores the need for a deeper investigation into the pathways by which physical activity mitigates negative emotions among college students.

Psychological resilience is considered an important protective factor in mitigating adversity and promoting the healthy development of individuals (Kim and McKenzie, 2014; Moeller et al., 2020). As renowned educator Cai Yuanpei said, "To develop a sound personality, one must start with physical education." This suggests that physical education helps build qualities like strength, perseverance, bravery, self-confidence, and a strong spirit when facing challenges. These qualities are closely linked to psychological resilience, a positive trait that helps individuals face, overcome, and learn from stressors (Fricke et al., 2017; Aperocho et al., 2021). Previous studies have shown a significant correlation between physical activity and enhanced psychological resilience in college students (Xu et al., 2021; Li and Guo, 2023). Thus, incorporating physical activity into their daily routines could be a promising approach to fostering resilience and promoting mental health.

Coping styles, another factor influencing how individuals manage stress, are the cognitive and behavioral efforts an individual makes to mitigate the negative effects of stress. Cognitive Appraisal Theory (CAT) Model, proposed by Richard S. Lazarus, suggests that humans can resolve dilemmas they face through psychological adjustments and effective coping efforts to reduce stress levels (Biggs et al., 2017). This theory underscores the proactive role individuals can play in managing their stress responses, highlighting the interplay between cognitive processes and emotional regulation. Coping styles are usually classified as positive and negative coping (Moeller et al., 2020). Research has shown that systematic training in physical dance can foster more positive coping styles and promote a healthier psychological state among college students (Bayram and Bilgel, 2008). Thus, through cognitive appraisal and the adoption of positive coping styles, potentially fostered by activities such as physical dance, individuals can effectively manage stress, enhancing their psychological well-being and overall quality of life.

Psychological resilience and positive coping styles are both positive psychological traits. Psychological resilience has been found to predict the adoption of positive coping styles and inversely predict negative ones (Blanco et al., 2008). Individuals exhibiting high psychological resilience tend to adopt positive coping styles and are more proactive in addressing and resolving negative emotions (Gong et al., 2023; Xu and Yang, 2023). Therefore, the mechanism through which physical activity affects negative emotions may be attributed to the influence of psychological resilience and coping styles on college students' negative emotions.

In summary, our study investigates the impact of physical activity on negative emotions, namely depression, anxiety, and stress, among college students. We aim to explore the mediating roles of psychological resilience and coping styles in this relationship. Specifically, we examine how psychological resilience mediates the relationship between physical activity and negative emotions, how coping styles mediate this relationship, and how psychological resilience and coping styles act as chained mediators. Chained mediation, also known as sequential mediation, is a statistical approach where an independent variable affects a dependent variable through a sequence of mediator variables (Imai et al., 2010). This research is intended to provide theoretical references and practical insights for mitigating negative emotional states in college students. Consequently, the hypotheses of this study include H1: Physical activity can significantly negatively predict negative emotions among college students; H2: Psychological resilience mediates the relationship between physical activity and the negative emotions of college students; H3: Coping styles mediate the relationship between physical activity and college students' negative emotions; H4: Psychological resilience and coping styles play a chained mediating role between physical activity and negative emotions in college students. The proposed model for our research hypothesis is depicted in Figure 1.

Methods

Study population and sampling method

The study population was selected using a stratified random sampling method. Three cities (Hangzhou, Nanjing, and Wenzhou) were randomly selected from the East China region, and then five colleges were randomly selected from these three cities. The survey was conducted from September 2022 to December 2022. According to the sample size calculation method (Preacher and Kelley, 2011), the estimated sample size ranges from 380 to 759. We expanded our analysis to include a larger sample of 1,420 undergraduate students from freshman to senior year.

Recruitment

The study included participants who met the following criteria: (1) aged between 17 and 25 years old, and (2) enrolled as undergraduate students at the university. The focus on undergraduate students was attributed to their unique developmental stage and specific academic pressures. Additionally, physical education classes, which are mandatory only for undergraduates, are not typically a part of graduate programs in China. This focus also allowed us to maintain sample homogeneity and data consistency, thereby improving the reliability and validity of our results. All participants provided informed consent and participated in the survey voluntarily. The study excluded: (1) graduate students and intern students at the school, and (2) individuals employed by the schools.

Pilot survey

An initial survey was administered to eight college students across various academic levels to verify the questionnaire's validity. The primary aim of the pilot survey was to validate the comprehensibility and effectiveness of our questionnaire. We aimed to ensure that the questionnaire's questions could be widely understood and effectively gather the information required for our research. Based on the respondents' feedback, suitable modifications were made to the questionnaire.

Data collection

The investigators, all of whom are public physical education teachers at these universities, received unified training via Tencent meetings. After obtaining approval from the school leadership, they collaborated to complete the questionnaire collection. The questionnaires were collected through face-to-face interviews. Before data entry, errors were identified and corrected, and missing responses were completed, ensuring logical consistency. Questionnaires with

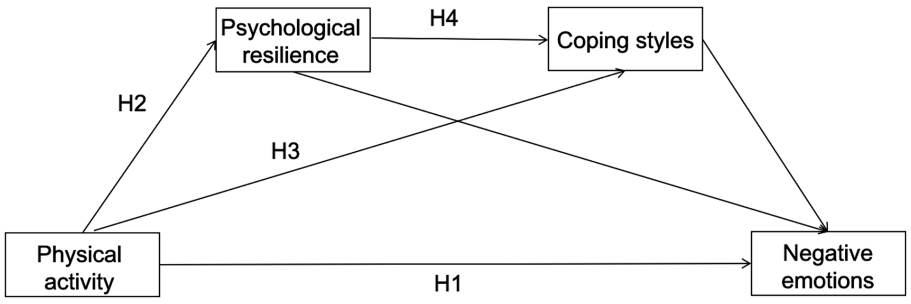

FIGURE 1
Hypothetical model proposed in this study.

clear logical inconsistencies and numerous missing responses were excluded. This approach aimed to enhance the precision of variable measurements within each subgroup. The selected colleges served as the targets for the survey.

Measurement instruments

Physical activity rating scale (PARS-3)

Physical activity was measured using the Physical Activity Rating Scale (PARS-3), developed by Japanese scholar Koshio Hashimoto and modified by Deqing Liang et al. (Liang and Liu, 1994). The scale uses a Likert 5-point scale with three dimensions: exercise intensity, time, and frequency. A 5-point Likert scale is a psychometric response method that allows respondents to express their level of agreement using the following points: (1) Strongly Disagree, (2) Disagree, (3) Neither Agree nor Disagree, (4) Agree, and (5) Strongly Agree. The scoring formula was: physical activity = exercise intensity × (exercise time − 1) × exercise frequency score, with higher scores indicating greater physical activity. Specifically, scores ≤19 are categorized as low physical activity (LPA), scores between 20 and 42 as moderate physical activity (MPA), and scores ≥43 as vigorous physical activity (VPA). The retest reliability of the scale in this study was 0.678.

Connor-Davidson resilience scale (CD-RISC)

We adapted the Connor-Davidson Resilience Scale (CD-RISC) developed by Connor and Davidson and revised by Xiaonan Yu et al. (Yu et al., 2011). The modifications were made to create a culturally relevant and psychometrically sound Chinese version of the scale, ensuring its applicability to Chinese-speaking populations. The scale consists of 25 items: 13 for resilience, four for optimism, and eight for self-improvement. A Likert 5-point scale was used for scoring. The internal consistency (alpha) coefficient of the scale in this study was 0.87.

Simplified coping style questionnaire (SCSQ)

The Simplified Coping Style Questionnaire (SCSQ) is a 20-item instrument that was developed by Xie (1998). The SCSQ measures two types of coping strategies: positive coping and negative coping. Positive coping strategies are constructive ways individuals deal with stress, such as seeking social support, practicing relaxation strategies, or problem-solving. Negative coping strategies, on the other hand, are behaviors that might temporarily reduce stress but could have long-term detrimental effects, such as avoidance or turning to alcohol or drugs. Using the Likert 4-level scoring method, 'not adopted' is scored 0, 'occasionally adopted' is scored 1, 'sometimes adopted' is scored 2, and 'often adopted' is scored 3. This is used to measure the level of positive and negative coping when an individual encounters stress. The scale has been widely used in China and has demonstrated high reliability and validity. In this study, the alpha coefficient of the positive coping subscale was 0.84, and that of the negative coping style subscale was 0.76.

Depression anxiety and stress scale (DASS)

The Depression Anxiety and Stress Scale (DASS-21), originally developed by Lovibond et al. in 1995, was used in this study in its Simplified Chinese version as revised by Gong et al. (2010). The adaptations aimed to ensure cultural relevance and psychometric validity for Chinese-speaking populations. The scale contains 21 items, with seven items each for the three subscales of depression, anxiety, and stress. Each item is scored on a 4-point scale ranging from 0 ("does not match") to 3 ("always matches"). The score for each subscale is obtained by multiplying the sum of its item scores by two, with higher scores indicating a greater likelihood of experiencing the respective emotion.

Data processing and analysis

The study's data analysis was conducted using IBM SPSS 22.0 and the PROCESS V3.5 plug-in, chosen for their robust analytical capabilities, compatibility, and the plug-in's mediation and moderation analysis features. The variables examined in the correlation and regression analyses were carefully selected based on their relevance to the study's objectives. These variables were subjected to descriptive analysis to provide a summary of their basic features and distributions. ANOVA was conducted to compare the means of these variables across different groups, providing insights into their relationships. Regression analysis was used to understand the predictive relationships between these variables. To validate the mediating effects between variables, a bias-corrected nonparametric bootstrap 95% confidence interval estimation was chosen. This method, involving 5,000 repetitions of sampling, was selected for its advantages in bias correction, skewness adjustment, versatility, and ease of implementation.

Additionally, given that the data in our study is self-reported, there is a potential for common method bias. During the testing process with college students, we emphasized the anonymity and confidentiality of the questionnaire, and clarified that the data is solely for scientific research purposes, in order to control the sources of common method bias as much as possible. Furthermore, we employed Harman's single-factor test (Baumgartner et al., 2021) to check for common method bias.

Results

Data collection and response rates

From September 2022 to December 2022, this survey-based, cross-sectional study collected data from 1,380 college students across five universities in three cities. Specifically, a total of 1,420 questionnaires were distributed to randomly selected students in physical education classes across these colleges. Of these, 1,397 were recovered, and after excluding invalid questionnaires, 1,380 valid responses remained. The recovery rate was 98.3%, and the validity rate was 97.1%. The high recovery rate can be attributed to the strong emphasis on academic participation in these institutions, and no additional incentives were provided. The respondents included 649 freshmen (47%), 469 sophomores (34%), 193 juniors (14%), and 69 seniors (5%). There were 773 male students (56%) and 607 female students (44%).

Common method bias test

The results of an unrotated exploratory factor analysis using Harman's one-factor test extracted a total of 11 factors with eigenvalues

>1. The maximum variance explained by a single factor was 23.76%, which is less than the critical criterion of 40%. These results indicate that there is no serious common method bias in this study. Common method bias, if present, could potentially inflate the relationships between variables due to shared method variance, leading to erroneous conclusions. However, our test results alleviate these concerns. The fact that no single factor emerged or accounted for the majority of the covariance among the variables suggests that the relationships observed in our study are likely to be attributed to the constructs under investigation rather than to any potential method bias.

Impact of academic year and major on negative emotions

In this study, we explored the potential influences of both academic year (encompassing freshman, sophomore, junior, and senior stages) and major (including fields such as medicine, foreign languages, law, computer science, education, psychology, materials engineering, chemistry, pharmacy, electronic information, and others) on the prevalence of negative emotions among college students. We employed analysis of variance (ANOVA) with the aim of discerning any statistically significant disparities in the cumulative scores of negative emotions across diverse academic years and majors. Contrary to our expectations, the results revealed that these factors did not exert a significant impact on the reported intensity of negative emotions, as evidenced by p-values of 0.405 for academic year and 0.117 for major. This finding implies a uniformity in the experience of negative emotions across various academic progressions and fields of study. Consequently, our analysis lends support to the hypothesis that the intensity of negative emotions experienced by college students is not significantly influenced by their respective academic year or chosen major.

The relationship between physical activity, psychological resilience, coping styles, and negative emotions

The means (M), standard deviations (SD) and correlation matrices for physical activity, psychological resilience, coping styles and negative emotions are given in Table 1. The descriptive results of each variable indicate that the average amount of physical activity among college students is at a low level (Mean = 16.911, SD = 17.108). The large standard deviation suggests a wide range of physical activity levels among the students. This could be due to a variety of factors, such as differences in personal habits, academic workload, or access to sports facilities. Psychological resilience, categorized into tenacity, self-improvement, and optimism, along with coping styles, divided into positive and negative coping, and negative emotions, subdivided into depression, anxiety, and stress, form the core variables of our study. When encountering stress, college students tend to use positive coping strategies (Mean = 36.796, SD = 5.640) than negative coping (Mean = 18.944, SD = 4.585).

Our correlation statistical analysis (Table 1) reveals significant relationships between physical activity, psychological resilience, coping styles, and negative emotions. Specifically, physical activity is positively correlated with both psychological resilience ($r = 0.270$, $p < 0.001$) and positive coping ($r = 0.166$, $p < 0.001$), but negatively correlated with negative emotions ($r = -0.097$, $p < 0.001$).

Moreover, psychological resilience and positive coping share a significant positive correlation ($r = 0.602$, $p < 0.001$). Within the sub-dimensions of psychological resilience, tenacity ($r = 0.556$, $p < 0.001$), self-improvement ($r = 0.591$, $p < 0.001$), and optimism ($r = 0.515$, $p < 0.001$) all exhibit positive correlations with positive coping.

Psychological resilience is significantly negatively correlated with negative emotions ($r = -0.222$, $p < 0.001$), including its sub-dimensions: depression ($r = -0.253$, $p < 0.001$), anxiety ($r = -0.186$, $p < 0.001$), and stress ($r = -0.199$, $p < 0.001$). Similarly, positive coping is negatively correlated with negative emotions ($r = -0.187$, $p < 0.001$) and its sub-dimensions: depression ($r = -0.213$, $p < 0.001$), anxiety ($r = -0.155$, $p < 0.001$), and stress ($r = -0.167$, $p < 0.001$). While, negative coping is positively correlated with negative emotions ($r = 0.399$, $p < 0.001$) and its sub-dimensions: depression ($r = 0.389$, $p < 0.001$), anxiety ($r = 0.353$, $p < 0.001$), and stress ($r = 0.404$, $p < 0.001$).

These results suggest that individuals can develop a higher level of psychological resilience through physical activity, enabling them to better handle various challenges. It appears that college students prefer to employ positive coping strategies when dealing with stress and negative emotions. This preference may indicate that during physical activity, individuals tend to adopt positive coping mechanisms, such as seeking support and problem-solving, to minimize the experience of negative emotions.

The relationship between the amount of physical activity and negative emotions among college students of different genders

Previous studies have highlighted significant gender differences in physical activity levels (McCarthy and Warne, 2022). This study further explores gender differences among these variables, as shown in Table 2. We applied an independent samples t-test to compare the gender difference. As shown in Table 2, male students are significantly more physically active than female students ($p < 0.001$). The corresponding Cohen's d value is 0.453, suggesting a near-medium effect size. This aligns with previous findings suggesting that male students are generally more inclined towards active involvement in physical activities (Sisay, 2021; Xu et al., 2021). These findings underscore the potential benefits of promoting physical activity as a strategy to mitigate negative emotions among college students, particularly in males.

Regarding coping styles, significant differences were observed between male and female students in both positive ($p = 0.002$, Cohen's d = 0.173) and negative coping ($p = 0.028$, Cohen's d = 0.118) (Table 2). Specifically, female students tended to employ more positive strategies to manage stress, aligning with the general characteristics of emotional expression and support-seeking in female students (Chaplin, 2015). These results indicate that although the effect sizes of positive and negative coping strategies are small to tiny, they are still significant in terms of gender differences, suggesting that gender differences in coping strategies may have important implications for stress management and emotional regulation.

TABLE 1 Descriptive and correlation statistics of each variable ($n = 1,380$).

		Mean ± SD	1	2	3	4	5	6	7	8	9	10	11
1	Physical activity	16.911 ± 17.108	1										
2	Psychological resilience	10.553 ± 1.665	0.270**	1									
3	Tenacity	3.410 ± 0.574	0.270**	0.927**	1								
4	Self-improvement	3.682 ± 0.598	0.268**	0.937**	0.857**	1							
5	Optimism	3.461 ± 0.641	0.211**	0.894**	0.712**	0.733**	1						
6	Coping styles	/											
7	Positive coping	36.796 ± 5.640	0.166**	0.602**	0.556**	0.591**	0.515**	1					
8	Negative coping	18.944 ± 4.585	−0.020	0.061*	0.085*	−0.007	0.089*	0.199**	1				
9	Negative emotions	35.737 ± 12.658	−0.097**	−0.222**	−0.170**	−0.274**	−0.170**	−0.187**	0.399**	1			
10	Depression	11.496 ± 4.393	−0.111**	−0.253**	−0.201**	−0.311**	−0.187**	−0.213**	0.389**	0.952**	1		
11	Anxiety	11.719 ± 4.305	−0.094**	−0.186**	−0.132**	−0.236**	−0.144**	−0.155**	0.353**	0.959**	0.872**	1	
12	Stress	12.522 ± 4.539	−0.075*	−0.199**	−0.153**	−0.239**	−0.156**	−0.167**	0.404**	0.957**	0.861**	0.883**	1

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

TABLE 2 Analysis of gender differences among variables.

	Gender		*t*	*p*	Cohen's d
	Male ($n = 773$)	Female ($n = 607$)			
Physical activity	20.175	12.755	8.433	< 0.001**	0.453
Psychological resilience	10.628	10.457	1.919	0.055	0.123
Tenacity	3.457	3.350	3.523	< 0.001**	0.169
Self-improvement	3.705	3.653	1.630	0.103	0.088
Optimism	3.466	3.455	0.314	0.753	0.016
Coping styles					
Positive coping	30.308	31.115	−3.174	0.002*	0.173
Negative coping	23.980	23.299	2.193	0.028*	0.118
Negative emotions	37.088	34.016	4.606	< 0.001**	0.244
Depression	11.903	10.977	3.989	< 0.001**	0.211
Anxiety	12.197	11.110	4.789	< 0.001**	0.255
Stress	12.988	11.929	4.417	< 0.001**	0.235

*Indicates $p < 0.05$; **indicates $p < 0.001$. For Cohen's d: 0.2 is a small effect, 0.5 is a medium effect, and above 0.8 is a large effect.

The study also found that male students' overall negative emotion scores were significantly higher than female students ($p < 0.001$) (Table 2). Further analysis revealed significant gender differences in the dimensions of negative emotions, specifically depression ($p < 0.001$, Cohen's d = 0.211), anxiety ($p < 0.001$, Cohen's d = 0.255) and stress ($p < 0.001$, Cohen's d = 0.235). These Cohen's d values reflect "small" to "near-medium" effect sizes for gender differences in depression, anxiety, and stress. This finding corroborates past studies, suggesting that male students may be less likely to express emotions, leading to an accumulation of negative emotions (MacArthur, 2019; Sagar-Ouriaghli et al., 2020). It further underscores the importance of taking into account the extent and nuances of gender differences in the influence on negative emotions when formulating mental health interventions for college students.

Relationships between physical activity, psychological resilience, positive coping styles and negative emotions: a mediation effect test

In developing our model, we considered cities and colleges as potential random effect factors, hypothesizing they might influence the dependent variable—total negative emotions score. However, our

TABLE 3 Analysis of regression relationship among variables.

	Path	Effect(β)	*SE*	*t*	*p*	LLCI	ULCI
Direct effect	Physical activity→Negative emotions	−0.040	0.029	−1.403	0.161	−0.096	0.016
Indirect effect	Physical activity→Psychological resilience	0.255	0.028	9.126	<0.001**	0.200	0.310
	Physical activity→Positive coping	0.027	0.022	1.078	0.281	−0.022	0.075
	Psychological resilience→Positive coping	0.555	0.024	23.087	<0.001**	0.508	0.602
	Psychological resilience→Negative emotions	−0.174	0.033	−5.239	<0.001**	−0.240	−0.109
	Positive coping→Negative emotions	−0.107	0.033	−1.403	0.161	−0.096	0.016
Total effect	Physical activity→Negative emotions	−0.102	0.028	−3.601	<0.001**	−0.158	−0.047

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

TABLE 4 Mediating effect test among variables.

Path	Effect value	Bootstrap SE	Bootstrap 95%CI	
			LLCI	ULCI
Physical activity→Psychological resilience→Negative emotions	−0.0324	0.0084	−0.0503	−0.0173
Physical activity→Positive coping→Negative emotions	−0.0002	0.0014	−0.0033	0.0026
Physical activity→Psychological resilience→Positive coping→Negative emotions	−0.0099	0.0041	−0.0186	−0.0023

analysis revealed that the variance components for each random effect were zero. This suggests that the influence of cities and colleges as random factors is either extremely limited or virtually non-existent, indicating a consistent influence across different locations and institutions on the dependent measures.

To further understand the underlying mechanisms affecting negative emotions, we tested the mediating effects of psychological resilience and positive coping styles in the relationship between physical activity and negative emotions. We used Model 6 in SPSS PROCESS V3.3 (Hayes, 2013) to conduct the analyses and showed the results in Table 3.

Direct effects analysis

Physical activity demonstrated a direct, albeit non-statistically significant, influence on negative affect (effect size (β): −0.040, $t = -1.403$, $p = 0.161$). This indicates the potential for physical activity to mitigate negative emotions, possibly through the involvement of other mediating variables.

Indirect effects analysis

We employed the bias-corrected nonparametric percentile Bootstrap method to examine the indirect influence of physical activity on negative emotions via psychological resilience. Physical activity was found to have a significant indirect positive effect on negative emotions through psychological resilience ($\beta = 0.255$, $t = 9.126$, $p < 0.001$). This suggested that psychological resilience can serve as a beneficial psychological resource, aiding individuals in better managing life's stresses and dilemmas, and consequently reducing the incidence of negative emotions.

However, the indirect effect of physical activity on positive coping was not significant ($\beta = 0.027$, $t = 1.078$, $p = 0.281$), implying that other mediators might play a more crucial role in the process of physical activity fostering positive coping. Furthermore, psychological resilience demonstrated a significant positive indirect effect on positive coping ($\beta = 0.555$, $t = 23.087$, $p < 0.001$), underscoring the pivotal role of psychological resilience in promoting positive coping.

Psychological resilience exhibited a negative indirect effect via negative emotions ($\beta = -0.174$, $t = -5.239$, $p < 0.001$), suggesting that a deficiency in psychological resilience might be linked to increased negative emotions. While, positive coping demonstrated a non-significant negative indirect effect through negative emotions ($\beta = -0.107$, $t = -1.403$, $p = 0.161$), implying that positive coping strategies might not always succeed in diminishing negative affect.

Total effects analysis

The total effects analysis revealed a significant negative correlation ($\beta = -0.102$, $t = -3.601$, $p < 0.001$) between physical activity and negative emotions (Table 3). This suggests that physical activity could alleviate negative emotions by enhancing psychological resilience and coping styles. This outcome substantiates the validity of the hypothesized model H1.

Chain mediating effect analysis

The study examined the mediating effects of physical activity on negative emotions through psychological resilience. Although the direct effect of physical activity on negative emotions was negative, the path analysis results revealed that this negative effect was further amplified when mediated through psychological resilience (effect value: −0.0324, as shown in Table 4). In essence, physical activity was found to reduce the experience of negative emotions by enhancing psychological resilience. This finding is consistent with the theoretical perspective that physical activity can improve an individual's ability to manage life stress and emotional distress, thereby reducing the intensity of negative emotions (Stults-Kolehmainen and Sinha, 2014; Schultchen et al., 2019). These results provide empirical support for Hypothesis H2 of the model.

The mediating influence of physical activity on negative emotions through positive coping was further examined. However, path analysis revealed that the effect of physical activity on negative emotions, when mediated through positive coping, was not significant. Despite the small mediation effect size (effect value: −0.0002), its 95% confidence interval (−0.0033, 0.0026) encompasses zero. This could suggest the presence of other unconsidered mediating factors in the relationship between these two variables. These findings did not validate the hypothesis H3 of the model. The practical implications of these findings suggest that while positive coping may not significantly mediate the relationship between physical activity and negative emotions, it remains an important factor to consider in mental health interventions.

The study further examined the chain-mediated effect of physical activity on negative emotions through psychological resilience and positive coping. The results indicated a significant chain mediation effect on negative emotions (effect value: −0.0099). This underscores the influence of physical activity on negative emotions under the combined impact of psychological resilience and positive coping, thereby validating the hypothesis H4 of the model. This chain mediation effect provides a more comprehensive understanding of the relationship between physical activity and negative emotions, highlighting the importance of both psychological resilience and positive coping in this relationship.

The overall chain mediation model between physical activity and negative emotions among college students is depicted in Figure 2. The findings highlight the pivotal role of psychological resilience in mitigating negative emotions, suggesting that interventions for negative emotions can be made through psychological resilience and positive coping.

Discussion

Our findings suggest that physical activity indirectly serves as a substantial mitigating factor for negative emotions. The average level of physical activity among college students is relatively low, with a tendency towards using positive coping strategies when faced with negative emotions. Notably, our study found a positive correlation between the amount of physical activity and both psychological resilience and positive coping. Conversely, physical activity was negatively correlated with negative emotions, specifically depression, anxiety, and stress. Gender differences were also observed in our study. Male students were significantly more physically active than their female counterparts. However, female students exhibited higher levels of positive coping. In terms of negative emotions such as depression, anxiety, and stress, male students scored significantly higher than female students. Physical activity was found to have a significant overall effect on negative emotions. Furthermore, both psychological resilience and positive coping were identified as chain mediators in the relationship between physical activity and negative emotions.

The relationship between physical activity and negative emotions

Previous research has primarily employed scale measurements and experimental methods to gather data and quantitatively evaluate the impact of various physical activity programs and the extent of physical activity on the negative emotions of college students (Stults-Kolehmainen and Sinha, 2014; Churchill et al., 2021). These studies have proposed intervention strategies and methods, demonstrating that active physical activity can alleviate negative emotions, enhancing students' ability to cope with stress and bolstering their psychological resilience. Our study, however, concentrates on the direct and indirect effects of physical activity on the negative emotions of college students. It elucidates the relationship, mechanisms, and effects of physical activity on negative emotions by incorporating elements of psychological resilience and positive coping styles. The findings indicate a significant negative and indirect correlation between physical activity and negative emotions in college students. The total effect of physical activity significantly predicts a decrease in negative emotions, as evidenced in Table 3, thereby confirming Hypothesis H1.

Mediating effects of psychological resilience

Stressful emotions can disrupt an individual's internal balance, leading to a reconfiguration of perceptions and a variety of outcomes. Psychological resilience, a beneficial personality trait, serves as a crucial safeguard. It empowers individuals to withstand stress, swiftly

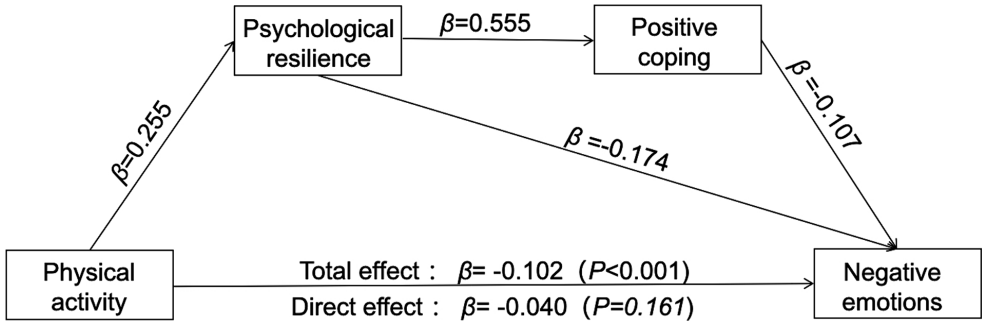

FIGURE 2
The chain mediating model between physical activity and negative emotions among college students.

adapt to their environment, and mitigate the harmful effects of adverse events (Troy et al., 2023). In the context of college students, psychological resilience plays a pivotal role in preserving their physical and mental equilibrium when they face stressful situations (Gong et al., 2023). Individuals with lower levels of psychological resilience may experience physical discomfort (e.g., shortness of breath, rapid heartbeat, dizziness), mental depression, and cognitive blankness when dealing with stress (Doan et al., 2023).

Psychological resilience can be bolstered through various means, such as self-improvement, setting appropriate life goals, moderating expectations, and maintaining harmonious family relationships. These strategies can assist college students in maintaining a positive psychological state (Wu et al., 2020; Kuang et al., 2024). However, the specific mechanisms through which physical activities strengthen psychological resilience and alleviate negative emotions have not been thoroughly studied.

Psychological resilience, a multidimensional construct with hierarchical characteristics, has been less explored in previous research, which has primarily focused on goals, emotions, and cognition (Chaplin, 2015; Zhang et al., 2022). This study aims to delve into three dimensions of resilience: individual self-improvement, optimism, and resilience, using a comprehensive scale of 25 items. Our findings reveal a robust positive correlation between physical activity and psychological resilience, a correlation that persists even when other control factors are considered. We extend the scope of previous research by demonstrating that physical activity primarily alleviates negative emotions through the comprehensive mediating role of psychological resilience. The divergence between our findings and those of previous studies (Wu et al., 2020; Xu et al., 2021; Gong et al., 2023) underscores the importance of considering the multidimensional nature of psychological resilience in future research, as the differences may be attributed to the varied scales used to measure psychological resilience.

This study affirms Hypothesis H2, indicating that individuals who engage in high levels of physical activity demonstrate increased resistance to negative emotions under stressful circumstances. This finding is consistent with the perspective that psychological resilience is a dynamic process influenced by various factors such as optimism, resilience, and self-improvement (Godara et al., 2022; Ijntema et al., 2023). These traits equip individuals with the capacity to adopt a more constructive problem-solving approach, thereby reducing the negative impact of risk factors and promoting individual adaptation and growth. This underscores the importance of physical activity in fostering psychological resilience and managing stress effectively.

Mediating effects of positive coping

Coping strategies are generally categorized into positive and negative types. Positive coping acts as a regulatory mechanism for stress, facilitating adaptive responses, whereas negative coping is often characterized by emotional distress and avoidance behaviors (Fteiha and Awwad, 2020). Our findings align with previous research styles (Moeller et al., 2020; Chen et al., 2022), indicating that regular physical activity is significantly associated with the adoption of positive coping. However, it appears to have no significant association with negative coping strategies, as indicated in Table 1. Engaging in physical activity is not merely an exercise but a proactive process that nurtures positive coping mechanisms. Despite this, our current study did not support the hypothesis (H3) that physical activity mitigates negative emotions in college students by significantly mediating through positive coping strategies, as shown in Table 3.

The sustained practice of physical activity has the potential to bolster psychological resilience and improve coping strategies among college students (Xu et al., 2021; Chen et al., 2022). This development promotes an active and engaged approach to challenges, as opposed to a passive or avoidance-based one. It empowers students to utilize their cognitive resources and physical vigor, to actively recalibrate their self-perception, regulate their emotions, and tackle obstacles directly. Thus, it is plausible that physical activity may enhance psychological resilience, thereby transforming their coping strategies.

Chain-mediating effects of psychological resilience and positive coping

Stressful events inevitably impact individuals, often leading to negative emotions and impaired cognitive functions. However, individuals with higher psychological resilience are more likely to employ positive coping strategies to address these issues. Prior research has indicated that factors such as interpersonal support, peer relationships, and sports friendships at school can foster a willingness to exercise among college students, thereby enhancing their physical activity behavior (Zhang et al., 2022; Zou et al., 2023). Additionally, family parental support, social support, and teacher support can also bolster college students' motivation and engagement in physical activity. These factors can aid college students in strengthening their commitment to exercise, implementing exercise behaviors, and fostering psychological resilience. This, in turn, enables them to adopt positive coping styles when faced with stress, thereby mitigating negative emotions and other mental health issues.

Our study's findings suggest that psychological resilience can inspire college students to maintain an optimistic attitude, perseverance, and self-improvement efforts in the face of adversity. They can positively adjust their cognition, confront the problem rather than evade it, and utilize their resources and skills to manage difficulties and alleviate negative emotions. This study further corroborates the fully mediating role of psychological resilience and positive coping styles between physical activity and negative emotions among college students. In other words, physical activity primarily mitigates negative emotions by enhancing psychological resilience and positive coping styles. Thus, hypothesis H4 is validated.

Our study also found significant gender differences in the emotional responses of college students, aligning with previous research (Chaplin, 2015; Graves et al., 2021; McCarthy and Warne, 2022). Female students demonstrated higher levels of positive coping, while male students exhibited more negative emotions, including anxiety, depression, and stress. Notably, male students' overall negative emotion scores were significantly higher than those of female students. These gender differences have practical implications for designing interventions or support programs for male and female students. For male students, an increased focus can be placed on emotion management and stress coping. This could include counseling services and training programs that enhance their emotional regulation skills.

For female students, the emphasis could be on fostering the development of positive coping mechanisms. This might involve promoting positive thinking, self-affirmation, and enhancing self-efficacy.

This study underscores the importance of focusing on the physical activity behavior of college students. It advocates for attention to the university physical education curriculum, calling for curriculum reform and innovation, and the provision of optimal physical education courses. The study further emphasizes the need for qualified physical education teachers who can guide students and help them realize the benefits of physical activity in terms of physical fitness, personality development, and willpower. In addition, the study suggests the implementation of specialized courses tailored to students of different genders. These courses could provide customized exercise programs and emotional management strategies to cater to their unique needs. By understanding and addressing these gender differences, colleges can more effectively support the mental health and well-being of all students. This approach fosters a healthier and more inclusive campus environment, thereby enhancing the overall student experience.

Limitations and prospects

While this study offers valuable insights into the relationship between physical activity, psychological resilience, positive coping styles, and negative emotions, it's important to interpret the results with caution due to certain limitations. The self-report method used to measure the intensity, duration, and frequency of participants' daily physical activity may not accurately represent their actual levels. Future research could benefit from more objective data collection methods, such as using wearable electronic devices. Additionally, this cross-sectional study limits the understanding of potential causal relationships over time. A longitudinal design in future studies could provide more comprehensive insights. Furthermore, potential confounding variables, such as financial means, access to resources, parental support, and upbringing, could influence the observed relationships. Future research should consider these variables for a more holistic understanding of the interplay between physical activity, coping skills, and emotional well-being.

Suggestions and strategies

Reducing pressure and encouraging physical activity

The education department should take appropriate measures to reduce the pressure on college students. Concurrently, the sports department should encourage students to engage in physical activity. Attention should be paid to the quality of physical education classes in colleges and universities, and students should be encouraged to participate in extracurricular physical activities.

Developing a campus 'sports culture'

Developing a 'sports culture' on campus is important. However, it's essential to recognize that physical activity can take many forms outside traditional sports settings. Activities like walking clubs, yoga classes, and other recreational options can appeal to a wider range of individuals. Offering diverse and inclusive options that cater to different interests and preferences can encourage more campus engagement in physical activity.

Promoting student health

Several key strategies emerge to promote student health in a university setting. Firstly, promoting active lifestyles through increased physical activity is crucial. This not only fosters healthier habits but also provides a natural outlet for stress and negative emotions. Secondly, developing mental resilience can significantly enhance a student's ability to cope with the pressures of university life. This can be achieved through targeted training and support, equipping students with effective coping strategies such as positive thinking and problem-solving.

Addressing gender differences and fostering community

Recognizing and addressing gender differences is another important aspect. Tailored interventions, such as specific exercise programs and emotional management strategies for female students, can provide more targeted support. Creating a healthy and active environment on campus, with a strong emphasis on sports culture, can further encourage participation in physical activities. Finally, establishing a student mutual support network can foster a sense of community and mutual support. These strategies, when implemented effectively, can significantly improve the overall health and well-being of college students.

Conclusion

In the context of increasing mental health concerns among college students, our study reveals a significant indirect association between physical activity and the mitigation of negative emotions such as depression, anxiety, and stress. This relationship is mediated by psychological resilience and positive coping styles. These findings contribute to the existing literature, providing a theoretical basis for practical interventions and emphasizing the importance of regular physical activity in improving the overall health and well-being of college students. We recommend incorporating physical activity promotion into existing educational programs and advocate for further research into the relationship between physical activity and mental health.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Ethics Committee of Xiamen Medical College. All participants gave their written informed consent to participate in this study.

Author contributions

ML: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. HL: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – review & editing, Writing – original draft. ZQ: Data curation, Formal analysis, Validation, Writing – review & editing. YT: Software, Writing – review & editing. WY: Resources, Writing – review & editing. RL: Project administration, Resources, Supervision, Validation, 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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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Carlos López-Serrano,
Polytechnic University of Madrid, Spain
Sonia García Merino,
Universidad Francisco de Vitoria, Spain

*CORRESPONDENCE
Noelia Belando-Pedreño
✉ noelia.belando@universidadeuropea.es

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Acute effects on the psychological perception of university students after participation in the "RegulACTION" workshop for the improvement of emotional health and promotion of an active lifestyle

Noelia Belando-Pedreño*, Daniel Mendoza-Castejón and Carlos E. López

Sport Science Faculty, European University of Madrid, Villaviciosa de Odón, Spain

Introduction: Prospective research in Health Sciences and Sports Sciences warns of the need to design and implement educational program at the different stages of human development, that promote emotional competences, interpersonal competences, an adequate level of healthy physical activity as well as adherence to the Mediterranean diet and a more active lifestyle on a physical and social level. The main objective of the study was to design an intervention program on intra-and interpersonal competences together with emotional education, nutritional education and healthy physical activity, called 'RegulACTION'.

Methods: The preliminary study sample consisted of 11 participants aged 21–28 years (M = 5.00, SD = 8.76) (8 female and 3 males) university students. An *ad hoc* questionnaire was elaborated to evaluate the participant's perception of the usefulness of the 'RegulACTION' experience and a semi-structured interview of 5 questions to assess their perception, identification of their emotions, awareness of their cognitions, emotions and behaviors in the different areas of their lives.

Results: The descriptive results show that the participants are receptive to continuing training in the regulation of cognitions (thoughts) and emotions to increase their satisfaction in different areas of their lives. Regarding the qualitative results, the participants' perception, collected verbatim, is that they feel the need to apply the knowledge about personal and social emotions, as well as healthy behavior in terms of nutrition and exercise, in their daily lives.

Discussion: The 'RegulACTION' program is designed based on the assessment of the prevalence of mental illness in the young adult and adult population, in line with the literature review in the area of knowledge of the theory of emotions, motivational theories and on the occasion of the development of a workshop organized.

KEYWORDS

emotional regulation, motivation, biopsychosocial model, active lifestyle, interpersonal skills, youth population

1 Introduction

Promoting healthy habits is an essential aspect of modern education, especially in the stages of basic training. This concept is progressively integrated into curricula at all educational levels. As per the World Health Organization (2013) the definition of *health*, is a state of complete physical, mental, and social well-being, rather than just the absence of illness. Mental health can be influenced by a variety of complex factors. In order to address this issue, it is necessary to implement comprehensive strategies that involve all social agents. Programs that combine physical activity, emotional work, and motivation development can be helpful in modifying harmful behaviors and increasing satisfaction in acquiring healthy habits. At the age of majority, individuals are often expected to act independently, without external guidance or mentoring. This can sometimes make it challenging for them to receive the support they may need.

The study clearly demonstrates the acute response to the level of importance, commitment, cognitive and emotional perception, and physical exercise techniques implemented in the 'RegulACTION' workshop for university students, building on the initial idea.

1.1 Theoretical background

The program 'RegulACTION' is based on well-established theories that explain human behavior through individual motivation in learning. It enhances the development of daily skills such as 'knowing how to be' and 'knowing how to do' (MacCann et al., 2020). The Theory of Emotional Intelligence (TEI) (Goleman, 1995), The Self-Determination Theory (SDT) (Deci and Ryan, 2000), the Theory of Planned Behavior (TPB) (Ajzen, 1991) and the biopsychosocial model (Kelly et al., 2009). According to Goleman (1995), emotional intelligence is based on five pillars that explain a person's emotional behavior: (1) Recognizing one's own emotions (being aware of one's own emotions and being able to identify a feeling as it occurs). (2) Emotion management concept (ability to manage one's feelings so that they are expressed appropriately is based on awareness of one's emotions). (3) Level of motivation. It is based on the idea that an emotion tends to drive towards an action. Therefore, emotion and motivation are intimately interrelated. Directing emotions, and the consequent motivation, toward the achievement of goals is essential for paying attention, self-motivation, self-management and creative activities. (4) Acknowledging the emotions of others without causing harm or damage to one's own state of mind or the emotional state of others. In this sense, empathy is a basic psychological construct for identifying, accepting and understanding the emotions of the other person. (5) The ability to relate to others (the ability to interact kindly, positively and effectively with others). In the same line of conceptual analysis of emotional intelligence, Mayer et al. (2000) and Mayer and Salovey (2007) establish four psychological bases analogous to Goleman's definition, such as: (1) emotional perception (emotions are perceived, identified, valued and expressed); (2) the cognitive dimension of emotion (emotions influence cognition, thoughts); (3) the understanding of one's own emotions and those of others in order to establish a common understanding of the emotions of others; (4) the understanding of one's own emotions and those of others in order to establish a common understanding of the emotions of others; (5) emotional management, the understanding of the emotions of others in order to establish a common understanding of the emotions of others. Over the past 3 years, following the pandemic, scientific evidence has focused on demonstrating the importance of emotional regulation in university students as a mediator of mental health in aspects such as body image, depression level (Wu et al., 2023), eating behavior, and coping with social fears (Zhang et al., 2021).

Depending on their level of self-determination (SDT), intrinsic motivation, extrinsic motivation or amotivation, students can increase their engagement in the learning process if their needs for perceived competence, personal autonomy and social relationships are met. In this sense, it has also been shown that the design of learning situations and the motivation of teachers in applying teaching processes directly influence their students' behavior (Shuo et al., 2022). We can then include the concept of the teacher as a model, where one's own attitude in the application of programs, such as the use of active and instructional methods based on a guided search with group tasks, could increase the impact on the psychological needs of individuals, as occurs in this program (Aloufi et al., 2021).

When considering the intention to perform an action, an individual's behavior is influenced by factors such as their predisposition toward carrying out the action and their perception of control over it. This includes their level of expertise and voluntariness in the decision to participate. Furthermore, social factors such as contextual pressure and peer observations can influence an individual's behavior prior to performance, whether positively or negatively (González Ruiz and Izquierdo Rus, 2023). Therefore, educational proposals that aim to create a positive climate and instil in students the belief that they can successfully change their habits with control and confidence, play a crucial role in the process, as suggested by the Theory of Planned Behavior (TPB). To achieve this, overcoming challenges related to physical activity is essential. Providing positive, interrogative, and prescriptive feedback can help individuals face future tasks or challenges of any kind.

Another important aspect in learning processes is emotional intelligence and its regulation. During training, it is crucial for individuals to develop multidimensional skills and work on socio-emotional capacities to successfully navigate personal areas of growth, as defined by Goleman (1995) in his conception of emotional intelligence. García Fernández and Giménez-Mas (2010) proposed an explanatory model of emotional intelligence that considers cognitive abilities (executive functions), personality traits, and abilities to process emotional information, among other factors. The authors base their application of EI on the study of internal or endogenous aspects, such as particular traits of the individual that can be innate or acquired through learning or knowledge, and external or exogenous aspects, which are behaviors based on adaptation to the environment.

The proposal presented here addresses elements such as responsibility (the ability to understand the consequences that actions may have in an intuited future), common sense or the ability to learn and unlearn, of an endogenous nature. In addition, situations are presented that promote the ability to adapt to the changing environment, empathy (the predisposition to understand what is happening to others and to accompany them in this process) or the ability to communicate assertively (using friendly language that is positive for us). Themselves and with others, thus making room for the external dimension of EI.

Finally, the biopsychosocial model (MBPS) is included as a reference, which aims to healthy habits and an active lifestyle in the population. As mentioned above, the search for a state of overall wellbeing for the individual involves trying to develop the maintenance of comprehensive health throughout the different stages of life. This multifactorial approach to health needs to be promoted from the earliest ages through to adulthood, with particular attention being paid to the behavioral level of the youngest, referring to psychosocial behaviors such as personal and social responsibility, self-management of emotions, empathy, social connectedness, among others (Wright and Burton, 2008; Hellison, 2011). If adequate levels of daily physical activity are not achieved, the help that strategies to increase levels of physical activity can provide in the same classroom, combined with the stimulation of cognitive skills and using the stimulation of emotional intelligence, could alleviate these deficiencies to some extent, as has been demonstrated in young students (Ibaibarriaga-Toset and Tejero-González, 2023), and be associated with better academic performance. However, it seems that in higher education these expectations are lost by ceding the autonomy of these issues to the students themselves, which represents an enormous potential loss for students of this age (Carballo-Fazanes et al., 2020; Guedes et al., 2021).

More physically and cognitively active behaviors, voluntary participation in this type of proposals, can improve the general health status of these students, as well as provide this population with psychological tools that correspond to a greater satisfaction of NPBs (Manzano-Sánchez and Valero-Valenzuela, 2019; Ismailov and Chiu, 2022), preserving the general well-being of the youngest. As previously mentioned, this type of proposal can also focus on the regular participation in physical activities in interaction with the social environment, the improvement of the general physical condition and the perception of achieving optimal real and perceived motor competence or "motor literacy" (integration of knowledge, procedures, attitudes and emotions related to motor behavior), as has been observed in previous educational stages (Quarmby et al., 2019; Whitehead, 2019). This is why it is so interesting to intervene at this crucial stage, when new changes are occurring in students' living conditions, which can alter such important aspects as personal emotional relationships with a partner, friends or family, personal care (sleep, rest, nutrition, physical condition, mental health) and, of course, trying to address one of the main current problems, obesity (Koliaki et al., 2023), or changes in the level of stress demand on a daily basis, combining occasions, studies and work, and more, as has been demonstrated after the COVID-19 pandemic (Hirano, 2023).

1.2 Aim

The main objective of this study was to evaluate the perception of young university students regarding the importance of working on emotional regulation, awareness of cognitions (thoughts), analysis of eating behavior, and physical exercise behavior following their participation in the 'RegulACTION' workshop. It was hypothesized that the 'RegulACTION' workshop, based on training strategies for cognition, emotional regulation, analysis of emotions and nutrition, and the practice of exercise techniques, would improve the perception of young university students about the importance of working on the cognitive, emotional, nutritional, and physical dimensions contributing to comprehensive well-being.

2 Materials and methods

2.1 Research design

The research design corresponds to a preliminary study and methodological development design of an educational program. The study develops a quantitative type of research (Sampieri, 2014), a descriptive subtype or approach (collection, analysis and presentation of data through quantitative measures) and a qualitative one for the collection of participants' perceptions of their experiences.

2.2 Participants

2.2.1 Sample recruitment

The sample consisted of 11 participants aged 21–28 years ($M = 35.00$, $SD = 8.76$) (8 female and 3 male) university students from the Community of Madrid (Figure 1). Among the criteria for the selection of participants, the variables of age, gender, educational stage and socio-economic level were taken into account in order to guarantee the representativeness of the population under study. The sampling technique applied was non-probabilistic by accessibility (Otzen and Manterola, 2017). This study has been designed and carried out taking into account all the bioethical principles established by the Belmont Report (1979) and the Declaration of Helsinki (recovered by de Abajo, 2001) principles of autonomy, beneficence, justice and non-maleficence. In addition, this study was approved by the Ethics Committee of the European University of Madrid (code: CIPI/22.299).

2.2.2 Selection criteria

The inclusion criteria (indications given in the workshop registration form), young university students aged 18–35 years without diagnosed mental health pathology and without osteoarticular and muscular resections that prevented them from doing physical exercise.

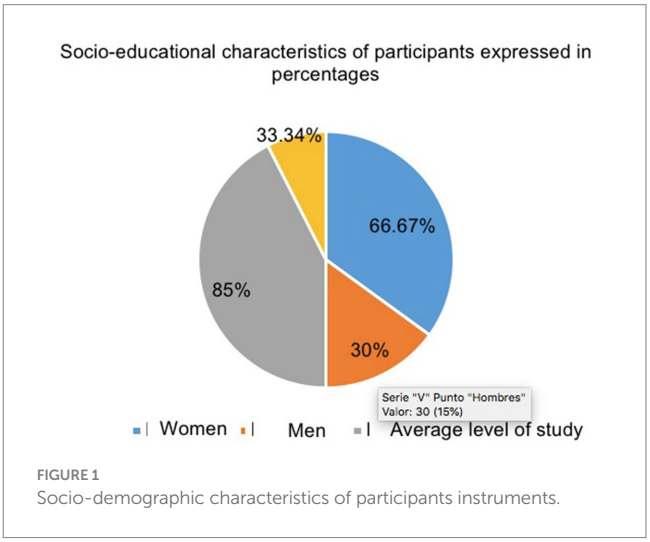

FIGURE 1
Socio-demographic characteristics of participants instruments.

2.3 Variables and measures

An *ad hoc* questionnaire was designed to assess participants' perceptions of the 'RegulACTION' training experience. This instrument combines the collection of quantitative data through 4 items (e.g.: level of importance of the lived experience on emotional regulation and physical exercise in the 'RegulACTION' workshop) rated on a Likert-type scale ranging from 1 (not at all or unimportant) to 10 (very important or very important). In addition, it included two open-ended questions, number 5 and number 6, to find out the participants' perceptions of the transferability of the workshop to different contexts of their lives: What has the experience of the workshop given you in terms of emotional regulation and emotional and physical well-being? What action can you take from now on that will bring you satisfaction with yourself? This questionnaire assesses the participants' perception of what the "RegulACTION" workshop experience has contributed to them (emotionally, in terms of their relationship with food, and regarding physical exercise behavior). In addition to the reliability test, the content validity of the items was checked by a panel of two experts who assessed whether the content of each item reflected what the researchers wanted to measure. Evidence of validity in relation to the response process was obtained firstly through a cognitive interview in the development phase and secondly from participants' comments during data collection (Angulo-Brunet et al., 2020).

2.4 Procedure

The sample was recruited through registration (online questionnaire in *Google forms* format) on the occasion of the 'RegulACTION' workshop, organized as a science outreach activity for the celebration of the European Researchers' Night 2023. The program was co-ordinated by a maximum of two university professors with a PhD in the field of physical activity and sport sciences and with knowledge in the health sciences (emotional education, motor behavior and nutrition education).

2.5 Design and application of the educational program

The educational workshop called 'RegulACTION' was structured along eight thematic lines (Table 1) related to emotional skills work, awareness of cognitions (thoughts), nutrition education and physical education (movement techniques) in relation to other curricular subjects. The maximum duration of each workshop was 2 h.

The "RegulACTION" workshop has been designed based on scientific findings regarding the psychological construct of "intrinsic motivation" analyzed and developed by Reeve (2002) (see Chapter 5, page 83), as well as on the internal and external motives that determine a person's behavior. The "RegulACTION" workshop also draws on the tenets of various theories that explain human behavior: Selft-Determination Theory (SDT), The Theory of Emotional Intelligence (TEI), Theory of Planned Behavior (TPB) as argued in the Introduction the present study.

Based on the indicated theories as the conceptual foundation, the workshop was structured into 3 parts (view Table 1):

2.5.1 First part

Concepts of emotional intelligence were worked on to identify cognitions (thoughts) and emotions linked to emotional well-being.

2.5.2 Second part

It focused on analyzing motivation for behavior change related to emotions, physical exercise behavior, and eating behavior (psycho-nutritional aspects of eating habits).

2.5.3 Third part

Activities were developed to raise awareness of how emotions are felt in the body, how to care for the body through breathing techniques and exercise techniques. In this part, a strength training session (20 min.) was also conducted, practicing basic exercise techniques.

Applied in activities recognizing different motivational states that students experience in their daily lives, or in activities aimed at understanding the reasons for engaging in sports. Additionally, participants experimented with two psychonutrition activities. In the first activity, they had to relate the types of food they consumed with academic or personal situations perceived as stressful. The second activity involved associating an emotion with a type of food and analyzing how they felt after eating that food in relation to the emotion.

The workshop included physical activities during which participants demonstrated a proactive attitude towards behavior, stimulated by positive, prescriptive, and interrogative feedback (subjective norm) and faced physical challenges that required decision-making within their group of peers (perception of behavioral control). The principles of emotional intelligence (Emotional Intelligence Theory, TEI) were used to work on emotional literacy following Dr. Hitzig's approach (reflection and discussion on the types of emotions and related attitudes that occur in different situations in the classroom, during play, in sports with friends, at home, in relationships with family, etc.).

2.6 Data analysis

A descriptive analysis (means and standard deviations) was carried out on the level of response to items 1 to 4 of the *ad hoc* questionnaire (response range from 1 [not at all/unimportant] to 10 [very important]) and the analysis of reliability (Cronbach's α and McDonald's ω, Ventura-León and Caycho-Rodríguez, 2017). To analyze the qualitative data extracted from the *ad hoc* questionnaire. First, the database was cleaned and the Mahalanobis distance was calculated to check for outliers. Next, the students' textual responses to qualitative items 5 and 6 of the *ad hoc* questionnaires were collected, regarding their perceptions of the importance, commitment, satisfaction and usefulness of the 'RegulACTION' workshop. All the information collected was incorporated into a single file stored in Excel 2010. The reliability and descriptive analyses were carried out using Jamovi [The Jamovi Project, (2023). Version 2.4 [computer software]. Obtained from https://www.jamovi.org].

3 Results

3.1 Quantitative results

Table 2 shows the descriptive results (means, standard deviations and reliability) obtained in items 1 to 4 of the questionnaire to evaluate

TABLE 1 Structure and contents of the RegulACTION workshop.

Structure	Contextualization	Practical content developed
1st part	Conceptualization and categorization of primary and social emotions.	Activity to identify the biological-adaptive, cognitive and socio-cultural nature of emotions.
2nd part	Motivation model for change (phases)	Activity for the identification of the "phase of the change" in which each participant is: "how you perceive yourself" at the moment on an emotional, physical level and in your social relationship with others
	Psychonutrition activities	The first activity, they had to relate the types of food they consumed with academic or personal situations perceived as stressful. The second activity involved associating an emotion with a type of food and analyzing how they felt after eating that food in relation to the emotion.
3rd part	Body awareness exercises (physical self-concept and identification of physical sensations of emotions). Breathing motor pattern regulation exercises (muscular synergy between diaphragm, abdominal muscles and pelvic floor). Body expression techniques: movements of the different body segments with music.	Practice with different exercise techniques to assess the impact on the participant's physiological and emotional responses, as well as motor competence (motor ability to respond to each exercise) and perception of fitness.
	Physical exercise techniques organized in the form of a general distribution circuit alternating lower and upper limb actions.	Circuit training organization (20 min.): (a) unipodal and bipodal squat (with and without load); (b) shoulder press (with and without load), (c) biceps curl (with and without load), unilateral traction (unilateral rowing) of upper limbs (with load CE 7–8 [12]).

TABLE 2 Descriptive data and reliability on the assessment of experience in simulated practice.

Items	*M*	*SD*	Cronbach's alpha	McDonald's ω
1. Level of importance of the lived experience on emotional regulation and physical exercise from the 'RegulACTION' workshop	9.5	0.30	0.82	0.85
2. Degree of commitment to undertake an action that contributes to improving your level of satisfaction with yourself.	9.00	1.02		
3. Level of perception of your thoughts, emotions and way of facing complex daily situations that you have experienced in the 'RegulACTION' workshop.	8.00	0.97		
4. How much do you value continuing to do workshops on emotional regulation and active lifestyle on an emotional and physical level?	9.2	1.12		

M, media; SD, standard deviation.

the experience, the degree of application and the usefulness of the contents worked on in the workshop in other areas of their life (e.g., in physical exercise behavior, in the academic field), using a Likert-type scale of 0–10. The *ad hoc* instrument designed has robust internal consistency values with α of 0.82 and ω of 0.85 (Ventura-León and Caycho-Rodríguez, 2017). With regard to the most highly valued items, 1 (level of importance of the emotional experience and physical exercise experienced) and 4 (how much they value continuing this type of workshop), with a score of 9.2 out of 10, we found that participants are very receptive to continuing training in managing cognitions (thoughts) and experiencing emotions to increase their satisfaction in different areas of their lives. On the other hand, the score of 9.00 out of 10 in item 2, which deals with the degree of commitment they would acquire to "get going" in order to improve their satisfaction with themselves, is remarkable. Regarding item 3, which also received a high score, the awareness of the flow of thoughts and the relationship with the emotional experience could be more complex.

3.2 Qualitative results

Table 3 shows the perception of the participants, expressed literally, in response to the following semi-open questions from the *ad hoc* questionnaire: (5) *What has the workshop experience given you in terms of emotional regulation and emotional and physical well-being*? (6) *What action can you take from today that will give you satisfaction with yourself?*

4 Discussion

This study aimed to test the importance, level of commitment and perceptions of cognitive and emotional simulation and physical exercise in these university students participating in the 'RegulACTION' workshop as an integrative training strategy for adequate emotional education, cognitive perception and promotion of an active lifestyle.

TABLE 3 The following are some of the most representative responses concerning items 5 and 6.

Item	Responses
5. What has the experience of the workshop brought you in relation to emotional regulation and emotional and physical wellbeing?	*Understand the power of emotions* *New ways of avoiding intrusive thoughts.*
	Be aware of the many internal tools I have to help me improve my emotional life and therefore my physical condition and that of everyone around me.
	It is important to understand how to manage intense emotions and recover from them.
	Adopting a positive mindset towards oneself and society can be helpful.
	I have realized that I need to delve deeper into what I feel and how this affects my daily life. Yes, emotions do influence the amount of exercise I do.
	I did not realize that emotions could affect me physically. The workshop has helped me identify it.
	The workshop has made me aware that my emotions affect my social relationships.
6. What action can you do from today that will bring you satisfaction with yourself? Body opening.	Avoid being overly self-critical.
	Refrain from mentally beating oneself up and thinking 'I am not good enough for what I propose.'
	Develop habits that promote both physical and mental well-being.
	Schedule an activity that involves close companions to share exercise time.
	I need help from an exercise professional to work on strength and feel better.
	I am going to dedicate 2 to 3 times a week to do physical exercise. The workshop has helped me see the need to move and improve my physical condition.
	I am going to include more protein in my diet and train for strength at least twice a week with an exercise professional.

Research has shown that limiting and restrictive thoughts towards oneself can lead to a loss of confidence in the learning process. This has been particularly evident during the COVID-19 pandemic (Romero-Blanco et al., 2020; Gavín Chocano and García Martínez, 2023). This can be very disabling in their academic progress, but by applying rationalization when these thoughts appear, it can be addressed in a better way through critical thinking (Cangalaya Sevillano, 2020). Emotions are a key factor in learning, and negative emotional states can negatively affect the learning process. It is widely acknowledged that emotion and cognition are closely linked. Emotions can have a significant impact on attention, memory, motivation, and decision-making processes. This is particularly relevant in academic research and evaluative testing (Urquijo et al., 2014; Elizondo Moreno et al., 2018). As item 3 suggests, it is crucial for students to learn how to recognize and manage negative thoughts, regulate emotions in personal and social contexts, in order to enhance their well-being and academic performance (Hendrie Kupczyszyn and Bastacini, 2020). The management and regulation of one's own emotions can contribute to improving perceived self-efficacy (Torre and Lieberman, 2018), reducing uncertainty, and facilitating concentration on critical learning points (Andrés et al., 2017; García-Ros et al., 2023). Regarding the importance and level of commitment of the participants towards using the proposed tools and continuing to explore this type of training (items 4 and 5), they were highly valued. Improving the classroom climate and providing intrapersonal tools for daily life, both inside and outside the classroom, can benefit students in their personal relationships with teachers, classmates, friends, and family. These benefits may also be reflected in their academic performance (Kritikou and Giovazolias, 2022). After revisiting these aspects in the qualitative open questions, the participants expressed that in order to relate adequately to themselves and their environment, they need to become aware of the emotions, the thoughts that lead them to certain emotions that determine their well-being (Jiménez-Parra et al., 2022a,b).

In young university students, it has been shown that there are aspects that can lead to a reduction in the commitment to daily and planned physical activity (restricted schedules, lack of time and lack of will, among others), which have a greater impact on the female sex. Therefore, programs should also focus on this core population (Kortabarria and Galarraga, 2021). With regard to increasing the level of physical activity at these ages (moderate to vigorous intensity), in accordance with the recommended dose (Franklin, 2021), it could contribute to improving psychological aspects such as self-esteem (Aloufi et al., 2021), the level of intrinsic motivation (Rodríguez-González et al., 2021), the development of emotional intelligence (Cazalla-Luna and Molero, 2014) and even better academic performance (Nuevo et al., 2021). Therefore, it would be necessary to continue to provide students with behavioral strategies to promote a healthy and sustainable bond over time with the practice of PE. In this task, educational centers (universities), through student service units and university extension activities, should offer training spaces and supervised physical exercise practice. All this, implemented with other strategies, psycho-nutritional education (healthy behavior with the way of eating) and sleep hygiene for a better rest and impact on the level of attention and perception necessary for cognitive and academic performance in the studies they carry out (Aloufi et al., 2021).

4.1 Limitations of the study

Limitations of the study include the selection of the sample, which was based on accessibility and not randomized, which affects the external validity of the study. Another aspect to consider

is the research design, which is a descriptive, cross-sectional pilot study. One of the significant limitations of the study is the small sample size so that the data can be extrapolated to the young population. However, we believe that the way in which the sample was recruited is a strength in that the researchers did not know the number of participants and typology (sociodemographic characteristics) of the participants until they carried out the workshop. The only criteria for inclusion (enrollment) in the workshop were a young population between 18 and 35 years of age, university students without diagnosed mental health pathology. Quasi-experimental studies with pre-and post-intervention data collection with experimental and control groups are necessary to verify the causal relationships between the variables analyzed. In terms of data collection, other quantitative questionnaires with psychometric properties validated in the population under study (Cronbach's Alpha or McDonald's Omega values) should be administered. Future research should take a quasi-experimental and longitudinal approach, with pre-and post-tests. It would also be necessary to use a randomized probabilistic sampling technique. Based on the observed results and other scientific evidence provided, educational workshops such as 'RegulACTION' emerge as an alternative teaching technique based on the incorporation of education in emotional skills, decision making for problem solving and education in a more active lifestyle within and outside of academic performance time. In this way, it contributes to the promotion of positive attitudes toward the various challenges faced by university students, supported by cognitive strategies, emotional regulation actions and the development of physical fitness through the practice of regular and supervised physical exercise. Therefore, this proposal simultaneously promotes emotional and prosocial behaviors (McMullen et al., 2016) and an increase in daily physical activity among young people (Merino-Barrero et al., 2019).

Future longitudinal quasi-experimental studies with repeated measures (pre-test and post-test) are needed, with a non-randomized control group (CG) and an experimental group (EG), analyzed using a quantitative methodology (tests and questionnaires) and a qualitative methodology (observational analysis). In addition, it is intended to check other variables such as (a) anthropometry (percentage of body composition and body perimeters), (b) nutritional status variables (food records, adherence to the Mediterranean diet measured with the *Predimed* questionnaire).

5 Conclusion and future practical applications of the RegulACTION workshop

As the main results of the preliminary study developed within the framework of the "RegulACTION" workshop application, a high level of commitment and appreciation of the participants was observed in the activities developed on the analysis of cognitions (thinking), awareness of emotions and the need to do physical exercise on a regular basis. The answers to the semi-open questions revealed verbalizations that showed their ability to reflect on the origin of their emotions in the areas of their lives (personal, domestic, work and social), the ability to become aware of their thoughts, emotions and behaviors, and how this influenced their perception of the world around them. (e.g., "I am aware of the many internal tools I have to help me improve my emotional life and therefore my physical condition and that of everyone around me").

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 the European University of Madrid (code: CIPI/22.299). 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

NB-P: Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. DM-C: Writing – original draft, Methodology, Investigation, Conceptualization. CL: Writing – review & editing, Supervision, Investigation, 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.

Publisher's note

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EDITED BY
Carla Maria Chicau Costa Borrego,
Polytechnic Institute of Santarém, Portugal

REVIEWED BY
Patxi León Guereño,
University of Deusto, Spain
Mário Borges,
London South Bank University,
United Kingdom
Francisco Serrano Romero,
Manukau Institute of Technology,
New Zealand
Mustafa Kayihan Erbas,
Aksaray University, Türkiye

*CORRESPONDENCE
Hyun-Duck Kim
✉ kimgolf@kmu.ac.kr

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Systematic review and meta-analysis of Chinese coach leadership and athlete satisfaction and cohesion

Jian Zhu[1,2], Meng Wang[1], Angelita Bautista Cruz[1] and Hyun-Duck Kim[1]*

[1]College of Physical Education, Keimyung University, Daegu, Republic of Korea, [2]Department of Physical Education, Zhongyuan University of Technology, Zhengzhou, China

Introduction: This meta-analysis investigates the relationship between coach leadership behaviors and athlete satisfaction and group cohesion within the realm of Chinese sports. The study also explores player sex and player classification as potential moderating variables. The primary focus is on evaluating the impact of coaching behaviors, as measured by the Leadership Scale for Sports, on athlete satisfaction and group cohesion.

Methods: Standard literature searches from China National Knowledge Infrastructure and Wanfang academic databases produced 26 studies encompassing a total of 319 effect sizes and a participant pool of 7,121 athletes across various sports.

Results: Using the Comprehensive Meta-Analysis (CMA) to examine relevant data, results reveal a moderate and positive association between coach leadership and athlete satisfaction (ES=0.412). Specifically, training and instruction (ES=0.531), positive feedback (ES=0.526), social support, and democratic decision-making exhibit positive effects, while autocratic behavior demonstrates a marginal positive effect. Similarly, a moderate positive relationship is identified between coach leadership and overall group cohesion (ES=0.275), with training and instruction (ES=0.396), social support (ES=0.356), positive feedback, and democratic behavior positively influencing cohesion. Conversely, autocratic behavior has a small negative impact on cohesion. Furthermore, female athletes (ES=0.603) and professional players (ES=0.544) display stronger positive associations between coach leadership and satisfaction.

Conclusion: These findings highlight the significance of diverse coaching behaviors aligned with player characteristics for fostering positive athlete satisfaction and group cohesion within the Chinese sports context, offering valuable guidance to Chinese coaches aiming to enhance their coaching strategies.

KEYWORDS

Chinese coaches, multidimensional model of leadership in sport, leadership scale for sports (LSS), athletic satisfaction, group cohesion, coaching behaviors, player sex differences, amateur and professional athletes

1 Introduction

Over the past several decades, China has emerged as a sports superpower. During the 1988 Seoul Summer Olympic Games, China ranked 11th with 5 gold, 11 silver, and 12 bronze medals. Subsequently, the country ascended to 4th place at both the 1992 and 1996 Olympic Games in Barcelona and Atlanta, respectively. Since then, China has consistently ranked

among the top 3 in the overall medal standings at every Summer Olympic Games (International Olympic Committee, 2023). China's dominance in sports is particularly evident in disciplines such as badminton, gymnastics, and volleyball (Zheng and Chen, 2016). Athletes in these disciplines often prevail in international competitions and major sporting events, such as the Olympics and World Championships. Their success is attributed to a combination of sport-specific factors, including government financial and policy support, access to superior facilities, and the opportunity to receive high-quality coaching and instruction (i.e., technical, tactical, and cognitive knowledge) from expert coaches (Zheng and Chen, 2016; Zheng et al., 2018).

Coaches in China, particularly those in elite sports, typically maintain direct contact with athletes, overseeing their holistic development. This involves creating a daily practice schedule to promote learning and improvement of sport-related skills through effective instructional strategies. Chinese coaches often assume additional roles as teachers and parental figures for athletes, especially because most professional athletes in China leave their homes at a young age to train and study in state-sponsored sports schools. Thus, coaches are responsible for overseeing athletes' daily routines outside training, such as sleeping, eating, resting, and studying (Liu et al., 2022). Given the extensive time Chinese athletes spend with their coaches, both within and outside the training and competition environment, coaches inevitably play a critical leadership role in various aspects of the athletes' sports careers and personal development. How coaches demonstrate these leadership behaviors can significantly impact athletes' sports participation and overall well-being.

The leadership of coaches has garnered substantial attention from scholars in the sport psychology domain because of its profound impact on athletes' sport-related outcomes (Gilbert and Trudel, 2004; Vella et al., 2010; Kim and Cruz, 2016, 2022; Cruz and Kim, 2017). Chinese scholars have recently shown considerable interest in exploring coach leadership as a research theme to gain deeper insights into the interactive dynamics between coaches and athletes, as well as the role of the coach as an influential contributor within the landscape of Chinese sports. Studies examining the effects of Chinese coaches' leadership styles and behaviors on athletes' psychological outcomes have identified both positive and negative associations (Lan, 2010; Zhu et al., 2017; Wang, 2021; Hsu, 2022; Zhang, 2022). Positive associations were observed when coaches displayed democratic or autocratic leadership styles and supportive behaviors, resulting in enhanced athlete satisfaction and cohesion (Jiao and Chen, 2007; Lan, 2010; Zhu et al., 2017; Tian et al., 2019; Hsu, 2022). Conversely, a negative association was observed when coaches employed autocratic leadership, leading to athletes' dissatisfaction and reduced perceived cohesion (Jiao and Chen, 2007; Lan, 2010; Tian et al., 2019). These findings underscore the pivotal role of coach leadership styles and behaviors in shaping the psychological states of athletes within the Chinese sports setting. Consequently, for Chinese coaches to be effective sports leaders, they must be mindful of the behaviors they exhibit toward their players. These behaviors should aim to foster positive athletic experiences, ultimately contributing to desirable personal and sport-specific outcomes.

When examining the impact of coaches' leadership behaviors on athletes' sport-related outcomes, researchers frequently employ the Multidimensional Model of Sports Leadership (MMSL) (Chelladurai, 2007). The MMSL posits that an athlete's satisfaction and performance depend on the required, actual, and preferred leader behaviors, which, in turn, can be influenced by situational, leader, and member characteristics.

To assess leadership behaviors using this model, Chelladurai and Saleh (2007) developed the Leadership Scale for Sports (LSS), comprising five subscales representing different components of sports leadership behaviors. These include instructional behaviors (training and instruction), decision-making behaviors (democratic and autocratic), and motivational tendencies (social support and positive feedback). Numerous studies have used this measurement tool to demonstrate that various factors can affect leader behavior, such as athletes' nationality (Weinberg and Gould, 2015), age (Martin et al., 1999; Weinberg and Gould, 2015), sex (Cruz and Kim, 2017; Yenen et al., 2022), and type of sport (Terry, 1984; Yenen et al., 2022). Additionally, other studies have revealed various consequences related to leader behavior, such as performance (Horn, 2008; Moen et al., 2014; Perera, 2019), burnout (Price and Weiss, 2000), anxiety (Price and Weiss, 2000), motivation (Price and Weiss, 2000; Jin et al., 2022), cohesion (Gardner et al., 1996; Ronayne, 2004), and satisfaction (Riemer and Chelladurai, 1998; Ntomali et al., 2017; Fouraki et al., 2020; Jin et al., 2022). Indeed, the results of these studies support the MMSL framework, indicating a dynamic interplay among antecedent conditions, types of leadership behaviors, and sports outcomes. Furthermore, the evidence underscores the importance of the LSS in identifying and evaluating coaches' leadership behaviors and determining which of these behaviors significantly affect the psychological and athletic outcomes of players.

A recent meta-analysis focused on coach leadership, primarily examining the MMSL framework and employing the LSS to assess the combined effects of coach leadership behaviors on athlete satisfaction and cohesion (Kim and Cruz, 2016). Athlete satisfaction is characterized as a positive emotional state resulting from athletes' evaluations of their athletic experiences, encompassing structures, processes, and outcomes (Chelladurai and Riemer, 1997). By contrast, sports cohesion refers to individuals' perceptions of the extent to which team members are united in pursuing sports objectives and goals (Carron, 1982). Their findings indicate that coaches' overall leadership behaviors were moderately and strongly related to cohesion and satisfaction, respectively. Notably, the training and instruction dimension of leadership behavior exhibited the most substantial impact on both psychological outcomes.

Building upon the insights from this existing meta-analytic study by Kim and Cruz (2016), a systematic review and analysis of the empirical studies available in Chinese literature on sports leadership would be valuable, enriching the body of knowledge in sports leadership literature. Moreover, given the distinctive context of Chinese sports—where athletes often spend almost their entire lives in sports schools, training and studying exclusively under the rigorous and detailed supervision of coaches—exposure to commanding and firm coaching behaviors is generally deemed acceptable. Coaches are generally viewed as second parents by players (Li et al., 2015; Babbitt, 2019) and as the primary managers of athletes' sports careers. Furthermore, due to the sport culture of the country that places greater expectations on winning as a function of sport level, athletes

Abbreviations: CI, Confidence interval; CMA, Comprehensive Meta-Analysis; ES, Effect size; LSS, Leadership Scale for Sports; MMSL, Multidimensional Model of Sports Leadership.

tend to trust their coaches more and rely on their authority and independent judgments concerning their athletic career. Likewise, since sport achievements and success are more valued, coaches are predisposed to adjust their coaching behaviors resulting from these expectancies (Amorose and Horn, 2000). Consequently, an authoritative leadership style may yield positive outcomes when such behavior is perceived as appropriate within the given context (Chelladurai, 2007). However, this assertion warrants further investigation.

This systematic meta-analysis consolidated relevant quantitative studies on sports leadership, evaluating the impact of coach leadership on athlete satisfaction and cohesion within the context of Chinese sports. Furthermore, the study examined player sex and sport classification as potential moderating variables in the relationship between coach leadership and athlete outcomes. By understanding the overall and specific dynamics of coach-athlete relationships in China, this meta-analytic review offers valuable insights for enhancing the leadership practices of Chinese coaches, particularly those behaviors that foster positive experiences in athletes' athletic participation.

This study addressed the following research questions: (1) What is the overall effect size (ES) for the relationship between coach leadership and satisfaction? (2) What is the overall ES for the relationship between coach leadership and cohesion? (3) What are the ESs for the relationships between each dimension of coach leadership and satisfaction and cohesion? (4) Does player sex moderate the relationship between coach leadership behavior and athletes' satisfaction and cohesion? (5) Does player sport classification moderate the relationship between coach leadership behavior and athletes' satisfaction and cohesion?

2 Method

2.1 Literature search

The authors conducted a systematic computer-based literature search and content analysis to collect relevant research studies addressing coach leadership behavior and target outcome variables following the PRISMA guidelines (Figure 1). The China National Knowledge Infrastructure and Wanfang academic databases were utilized to gather potential papers. The keywords used during the search process were leadership, coaching, coaches, leadership behavior, leadership sports scale, cohesion, (group) cohesion, and (athlete) satisfaction. Additionally, the authors manually searched for related articles in leading Chinese journals on sports psychology and sports management. The literature search covered the period from inception until April 2022. In this stage, a total of 408 articles were identified from the academic databases. Upon further screening and review articles, books, book chapters, conference proceedings and duplicates removed, 137 articles were considered qualified for further evaluation.

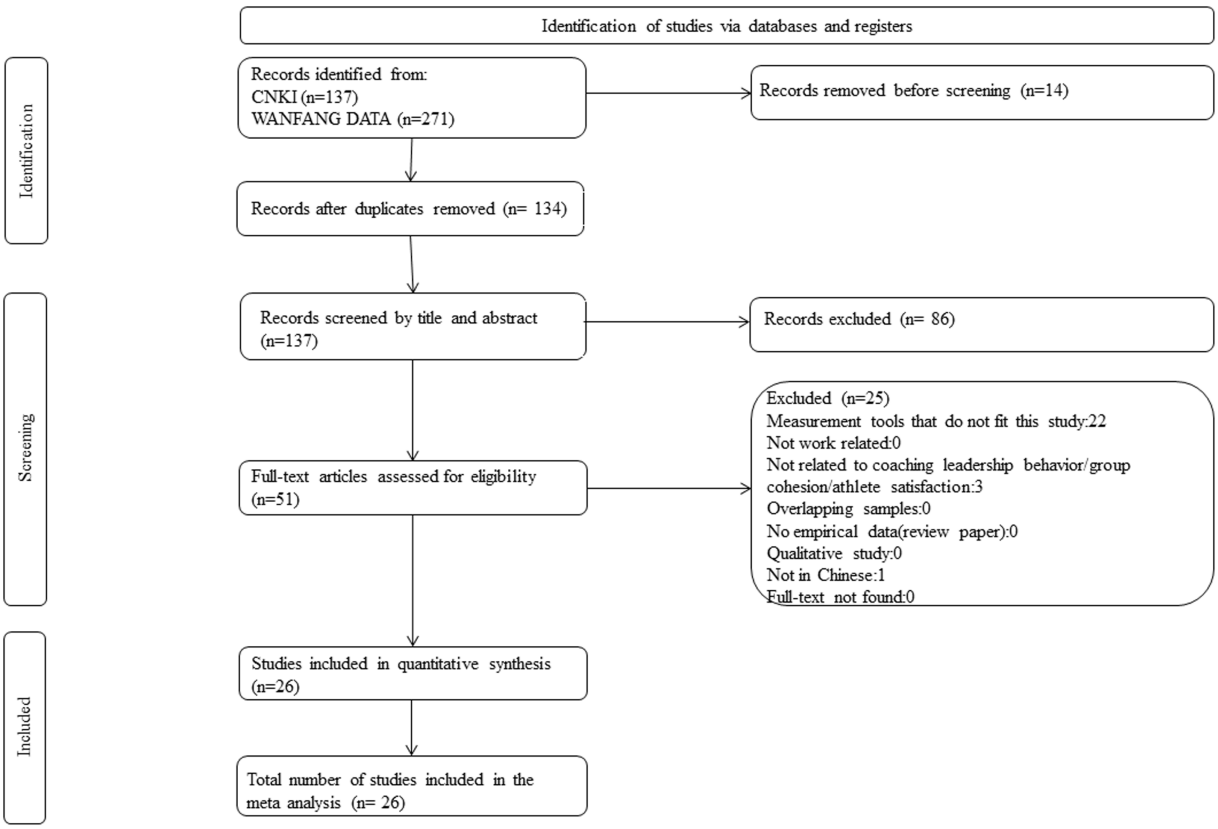

FIGURE 1
Flow diagram of study selection process following PRISMA procedure.

2.2 Inclusion criteria

To be included in the meta-analysis, studies should have (1) been published in academic journals; (2) employed a quantitative research design with Chinese sports coaches and athletes as participants; (3) evaluated coach leadership using the LSS; and (4) included relevant statistical variables such as correlation coefficient values and sample sizes to calculate the ES between coaching leadership behavior and satisfaction and/or cohesion. Studies that did not meet the inclusion criteria were excluded. Ultimately, 26 studies were accepted for inclusion in the meta-analysis.

2.3 Coding

Each study was reviewed and categorized based on its outcome variable(s). Two authors independently coded all relevant characteristics and statistical data from the studies. The third author reviewed the coding results and checked for discrepancies. The last author reassessed and rectified any observed coding discrepancies or errors. Finally, all authors reviewed the corrected coding list of studies for final confirmation.

A total of 319 ESs were coded from the 26 studies included in this meta-analysis. The sample comprised 7,121 participants, including both professional and amateur athletes from middle schools, high schools, colleges, and sports clubs. These participants were involved in a range of sports, including handball, basketball, soccer, volleyball, rowing, cheerleading, scuba diving, track and field, aerobics, and wrestling. Table 1 presents the characteristics of the included studies.

2.4 Meta-analytic tool

The Comprehensive Meta-Analysis (CMA) software (Borenstein et al., 2005) was utilized to calculate ESs from the selected studies. By converting the correlation coefficient and sample size from each study into Fisher's z scale, the CMA software computed the summary effect. Additionally, the confidence interval (CI) results generated by the CMA indicated variability in the estimated mean correlation. Following the

TABLE 1 Summary characteristics of Chinese coaching leadership studies using LSS.

#	Author and Year	Player sex	Player classification	Sample size	Type of sport	Dependent variable
1	Shi and Ji (2004)	Male	Amateur	165	Team	Satisfaction
2	Jiao and Chen (2007)	Female	Amateur	376	Team	Satisfaction
3	Zhang and Yin (2011)	Male	Amateur	207	Team	Satisfaction
4	Liao (2011)	Male/female	Amateur	130	No description	Satisfaction
5	Yan et al. (2012)	Male/female	Professional	184	Individual	Satisfaction
6	Cai and Wu (2014)	Male	Professional	339	Team	Satisfaction
7	Wang (2015)	Male	Amateur	136	Team	Satisfaction
8	Zhu et al. (2017)	Male/female	Professional	320	Team	Satisfaction
9	Wang (2018)	Female	Professional	196	Team	Satisfaction
10	Zhang (2019)	Male	Professional	274	Individual	Satisfaction
11	Liu (2021)	Female	Professional	283	Team	Satisfaction
12	Hsu (2022)	Male/female	Amateur	388	Team/ Individual	Satisfaction
13	Zhang (2022)	Female	Professional	438	Team	Satisfaction
14	Dai and Qiu (2022)	Male	Professional	304	Team	Satisfaction
15	Ma and Wang (2006)	Female	Professional	160	Team	Task and social cohesion
16	Zhang (2006)	Female	Amateur	581	Team/ Individual	Task and social cohesion
17	Zhu (2008)	Male	Professional	99	Team	Task and social cohesion/satisfaction
18	Zhang (2009)	Male/ female	Professional	343	No description	Task and social cohesion
19	Lan (2010)	Male	Amateur	465	Team	Task and social cohesion
20	Cui (2010)	No description	Professional	319	No description	Task and social cohesion
21	Li (2015)	Female	Amateur	218	Team	Task and social cohesion/satisfaction
22	Wu (2017)	Female	Amateur	297	Team	Task and social cohesion
23	Li (2017)	Female	Professional	167	Team	Task and social cohesion
24	Tian et al. (2019)	Male	Professional	144	Team	Task and social cohesion
25	Liu (2020)	Male	Professional	280	Team	Task and social cohesion
26	Wang (2021)	Female	Amateur	308	Team	Task and social cohesion

recommendation of Hunter and Schmidt (2004) when evaluating a relatively small number of studies, the random effects meta-analytic procedures were used. The resulting ESs were categorized as small (0.10), medium (0.30), and large (0.50) based on the benchmarks suggested by Cohen (1998).

3 Results

The potential for publication bias in studies concerning coach leadership, group cohesion, and athlete satisfaction was investigated (Supplementary Figure S1). The funnel plot for coach leadership and group cohesion studies displayed a symmetrical distribution of points on both sides, indicating no evidence of publication bias. Furthermore, Egger's regression test yielded an intercept value of 0.445, with $p > 0.05$, corroborating the absence of publication bias.

The distribution of points in the funnel plot of studies on coach leadership and athlete satisfaction was somewhat asymmetric, suggesting possible publication bias. The Egger's regression test intercept value was 0.448, $p < 0.05$, indicating potential bias. However, the Begg and Mazumdar rank correlation test yielded a value of 0.300, $p > 0.05$, suggesting no publication bias.

3.1 Relationship between coach leadership behavior and athlete satisfaction

The results showed a positive relationship between coach leadership and athlete satisfaction. The overall value of coach leadership concerning its effect on athlete satisfaction was computed as 0.412, suggesting that coach leadership has a moderate effect on athlete satisfaction (Table 2).

The effects of various leadership behaviors on athlete satisfaction were examined, with results indicating that training and instruction, as well as positive feedback, had large and positive impacts. By contrast, democratic behaviors and social support exhibited moderate and positive effects. Notably, although the mean ES of autocratic behavior was relatively small (0.074), its influence on athlete satisfaction was positive (see Table 3).

3.2 Relationship between coach leadership behavior and group cohesion

The results illustrated a positive relationship between coach leadership and group cohesion. The overall value of coach leadership concerning its effect on group cohesion was computed as 0.275, suggesting that coach leadership has a relatively modest and positive effect on overall group cohesion (see Table 4).

In the subcategory of group cohesion, both task and social cohesion exhibited positive relationships with coach leadership, with values of 0.286 and 0.264, respectively. These findings suggest a positive and moderately significant impact of coach leadership on the task and social cohesion of athletes (see Table 4).

The relationship between each leadership behavior and overall cohesion revealed that, except for autocratic leadership behavior, all other leadership behaviors exhibited positive and moderate associations with group cohesion. Specifically, training and instruction demonstrated the most pronounced positive and moderate impact on

TABLE 2 Overall meta-analysis of coach leadership and athlete satisfaction.

k	*Q*	*p-value*	ES	−95% CI	+95% CI	I^2	SE
16	1525.918	0.000	0.412	0.123	0.636	99.017	0.160

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effects size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error.

TABLE 3 Meta-analysis of the relationship between coach leadership dimensions and athlete satisfaction.

Leadership traits	*Q*	*p*	ES	−95% CI	+95% CI	I^2	SE
Training and Instruction ($k = 16$)	1768.706	0.001	0.531	0.249	0.731	99.152	0.186
Democratic ($k = 16$)	1871.320	0.008	0.438	0.122	0.674	99.198	0.197
Autocratic ($k = 16$)	1740.644	0.667	0.074	−0.256	0.388	99.138	0.183
Social Support ($k = 16$)	1712.522	0.001	0.492	0.203	0.702	99.124	0.180
Positive Feedback ($k = 15$)	1159.965	0.000	0.526	0.288	0.703	98.793	0.130

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effects size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error.

TABLE 4 Overall meta-analysis of coach leadership and group cohesion.

Factor	*Q*	*p*	ES	−95% CI	+95% CI	I^2	SE
Overall ($k = 12$)	84.496	0.000	0.275	0.184	0.362	86.982	0.013
Task ($k = 12$)	80.273	0.000	0.286	0.198	0.370	86.297	0.012
Social ($k = 12$)	100.328	0.000	0.264	0.164	0.358	89.036	0.015

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effects size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error.

group cohesion, followed by social support, democratic behavior, and positive feedback. Conversely, autocratic leadership had a negative effect on group cohesion, although the magnitude of this effect was minimal (see Table 5).

The relationships of each leadership dimension with task cohesion and social cohesion revealed positive and moderate associations of training and instruction, democratic, social support, and positive feedback leadership behaviors with both task and social cohesion. Conversely, autocratic behavior displayed a negative, albeit very weak, association with both task and social cohesion (see Table 5).

3.3 Relationship between coach leadership, cohesion, and satisfaction based on player sex

The mean ES for female athletes was 0.603 while that for male athletes was 0.439. This suggests that both male and female athletes demonstrated positive relationships between coach leadership and satisfaction. However, the mean ES was higher in female athletes compared to their male counterparts (see Table 6).

For the leadership-cohesion relationship, the mean ES for female athletes' group cohesion, task cohesion, and social cohesion was 0.232, 0.239, and 0.225, respectively. These values indicate that the relationships between coach leadership and group, task, and social cohesion were positive with moderate effects. Similarly, the mean ES for male athletes' group cohesion, task cohesion, and social cohesion was 0.383, 0.384, and 0.379, respectively, suggesting positive relationships between coach leadership and group, task, and social cohesion with moderate effects (see Table 7).

3.4 Relationship between coach leadership, cohesion, and satisfaction based on player classification

The relationship between coach leadership and athlete satisfaction was positive with moderate effects among amateur players (ES = 0.215). By contrast, coach leadership had a large and positive effect on athlete satisfaction among professional players (ES = 0.544) (see Table 8).

The relationship between leadership and cohesion revealed positive and moderate associations between coach leadership and group cohesion (ES = 0.283), task cohesion (ES = 0.283), and social cohesion (ES = 0.283) among amateur athletes. Similarly, the relationships between coach leadership and group cohesion (ES = 0.269), task cohesion (ES = 0.288), and social cohesion (ES = 0.249) were positive with moderate effects among professional athletes (see Table 9).

TABLE 5 Meta-analysis of the relationship between coach leadership dimensions and group cohesion.

Leadership dimension	Factor	Q	*p*	ES	−95% CI	+95% CI	I^2	SE
Training	Overall	183.454	< 0.01	0.396	0.271	0.508	94.004	0.028
And Instruction	TC	191.376	< 0.01	0.423	0.298	0.533	94.252	0.03
(k = 12)	SC	212.936	< 0.01	0.368	0.231	0.491	94.834	0.033
Democratic	Overall	122.016	< 0.01	0.346	0.241	0.443	90.985	0.019
(k = 12)	TC	171.657	< 0.01	0.369	0.246	0.48	91.657	0.026
	SC	118.908	< 0.01	0.321	0.216	0.419	90.749	0.018
Autocratic	Overall	255.397	< 0.01	−0.051	−0.214	0.114	95.693	0.04
(k = 12)	TC	229.726	< 0.01	−0.051	−0.205	0.106	95.212	0.036
	SC	314.003	< 0.01	−0.052	−0.232	0.131	96.497	0.049
Social Support	Overall	125.008	< 0.01	0.356	0.25	0.453	91.201	0.019
(k = 12)	TC	169.939	< 0.01	0.308	0.181	0.425	93.527	0.026
	SC	270.435	< 0.01	0.398	0.246	0.532	95.932	0.042
Positive Feedback	Overall	161.785	< 0.01	0.298	0.173	0.413	93.201	0.025
(k = 12)	TC	206.894	< 0.01	0.343	0.205	0.468	94.683	0.032
	SC	138.105	< 0.01	0.251	0.133	0.362	92.035	0.021

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effect size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error; TC, task cohesion; SC, social cohesion.

TABLE 6 Coach leadership and athlete satisfaction relationship based on player sex.

Player sex	*Q*	*p*	ES	−95% CI	+95% CI	I^2	SE
Female (k = 5)	1012.944	0.094	0.603	−0.118	0.908	99.605	0.635
Male (k = 7)	132.064	0.000	0.439	0.226	0.612	95.457	0.064

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effects size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error.

TABLE 7 Coach leadership and group cohesion relationship based on player sex.

Player sex	*Q*	*p*	ES	−95% CI	+95% CI	I^2	SE
Female ($k=6$)							
Overall	49.919	0.003	0.232	0.082	0.372	89.984	0.025
Task	49.896	0.002	0.239	0.089	0.379	89.979	0.025
Social	57.282	0.007	0.225	0.063	0.375	91.271	0.029
Male ($k=4$)							
Overall	10.215	0.000	0.383	0.271	0.484	70.630	0.011
Task	13.284	0.000	0.384	0.256	0.498	77.416	0.018
Social	10.095	0.000	0.379	0.268	0.481	70.282	0.013

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effects size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error; TC, task cohesion; SC, social cohesion.

TABLE 8 Coach leadership and athlete satisfaction relationship based on player classification.

Player classification	*Q*	*p*	ES	−95% CI	+95% CI	I^2	SE
Amateur ($k=7$)	146.392	0.083	0.215	−0.028	0.434	95.901	0.068
Professional ($k=9$)	1152.362	0.013	0.544	0.126	0.798	99.306	0.288

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level value of the heterogeneity test statistic; ES, weighted random effect size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error.

TABLE 9 Coach leadership and group cohesion relationship based on player classification.

Player classification	*Q*	*p*	ES	−95% CI	+95% CI	I^2	SE
Amateur ($k=5$)							
Overall	54.145	0.001	0.283	0.120	0.431	92.612	0.028
Task	48.689	0.000	0.283	0.128	0.424	91.785	0.025
Social	68.920	0.003	0.283	0.098	0.449	94.196	0.035
Professional ($k=7$)							
Overall	29.549	0.000	0.269	0.159	0.373	79.695	0.014
Task	31.414	0.000	0.288	0.176	0.394	80.901	0.015
Social	29.505	0.000	0.249	0.138	0.354	79.664	0.014

k, sample size; *Q*, heterogeneity test statistic; *p*, significance level of the heterogeneity test statistic; ES, weighted random effects size; CI, confidence interval; I^2, ratio of the magnitude of total heterogeneity between studies to total variance; SE, standard error; TC, task cohesion; SC, social cohesion.

4 Discussion

This study aimed to comprehensively examine the body of research focused on the impact of coach leadership, as measured by LSS on athlete satisfaction and group cohesion within the context of Chinese sport. Additionally, the study investigated players' sex and sports classification as moderating variables for the associations between the predictor and outcome variables. Overall, results revealed that the magnitude and direction of the relationship between the predictor and outcome variables are moderate and positive. Furthermore, player characteristics such as sex and sport classification were found to moderate the coach leadership-satisfaction/cohesion relationships.

4.1 Relationship between coach leadership and satisfaction

Overall, coach leadership was moderately and positively associated with athlete satisfaction. This result is relatively similar to that of a previous meta-analysis (Kim and Cruz, 2016), which also revealed a moderate association between coach leadership and satisfaction. However, the mean ES of the present study is slightly higher than that of the previous one (ES = 0.412 vs. ES = 0.357).

In terms of various dimensions of leadership behavior, the results indicated that all five dimensions are positively associated with athlete satisfaction, corroborating the findings of a previous study (Kim and Cruz, 2016). Specifically, training and instruction (ES = 0.531) and positive feedback (ES = 0.526) behaviors were found to exert large effects on athlete satisfaction. Social support and democratic behaviors demonstrated moderate effects, while autocratic behavior had a negligible effect. Although these results partially confirm the findings of a previous meta-analysis (Kim and Cruz, 2016), the current study revealed larger effects for training and instruction and positive feedback behaviors compared to the results of the earlier study (Kim and Cruz, 2016), which indicated only moderate effects for both behaviors (ES = 0.432 and 0.398, respectively). The study's inclusion criteria, particularly the exclusive sample population, could account for the discrepancy in results.

The results highlight that various training, decision-making, and motivational-related behaviors of coaches can affect the satisfaction levels of athletes, with training and instruction and positive feedback being the largest contributors to the leadership-satisfaction relationship. Therefore, the findings imply that Chinese coaches should extensively focus on delivering high-quality training and instruction to athletes and offer frequent positive feedback on their performance to enhance athletes' overall satisfaction with their athletic experience. Furthermore, Chinese coaches should encourage players to make decisions independently, provide relational support, and exercise control to instill discipline and foster long-term commitment to sports among athletes.

4.2 Relationship between coach leadership and cohesion

The results indicate that the overall magnitude of the relationship between coach leadership and group cohesion is moderate. Similarly, both types of group cohesion—task cohesion (ES = 0.286) and social cohesion (ES = 0.264)—demonstrated positive and moderate associations with coach leadership. These findings corroborate those of a similar meta-analytic study, which reported moderate ES values for the relationships between leadership and group cohesion (ES = 0.211), task cohesion (ES = 0.221), and social cohesion (ES = 0.201) (Kim and Cruz, 2016).

The association between each leadership dimension and group cohesion, including its subtypes, revealed that all behaviors—except for autocratic behavior—such as training and instruction, democratic, social support, and positive feedback, have a positive relationship with a moderate effect on the group, task, and social cohesion. These findings align with a previous meta-analysis that examined leadership dimensions of coaches using the LSS (Kim and Cruz, 2016). Notably, ESs in the current study are slightly higher than those reported in the earlier meta-analytic review. This suggests that when Chinese coaches frequently exhibit these leadership behaviors, players tend to feel more cohesive with their teammates and are more committed to achieving team goals.

By contrast, a negative correlation with a negligible ES is observed between autocratic behavior and group, task cohesion, and social cohesion. This suggests that a player's commitment to achieving the team's goal and interpersonal attraction with teammates tend to decrease when coaches are perceived as overly controlling, intimidating, and unsympathetic. However, crucial to note is not dismissing the possibility that autocratic behavior has any (negative) relationship with cohesion. This caution stems from the CI, encompassing the 0% null difference (Greenland et al., 2016), as observed in an earlier study (Kim and Cruz, 2016). Therefore, interpreting this result requires caution, and additional empirical studies are warranted to further explore the relationship between autocratic behavior and group cohesion, including its subtypes.

4.3 Relationship between coach leadership and athlete satisfaction and cohesion based on player sex

Previous studies have demonstrated that member characteristics can moderate the relationship between coach leadership and satisfaction (Kim and Cruz, 2016, 2022). Regarding player sex, coach leadership was positively associated with satisfaction in both males (ES = 0.439) and females (ES = 0.603); however, the relationship was stronger in females. This indicates that female athletes may experience greater satisfaction from positive coaching behaviors than male athletes.

Athletes' overall cohesion and cohesion subgroups demonstrated a positive association with coach leadership for both male and female players. Furthermore, although the magnitudes of the associations were moderate, the mean ES value was slightly higher in male than in female athletes. This suggests that the perception of unity to accomplish tasks and interpersonal attraction might be slightly better in male athletes than in female athletes when coaches exhibit positive leadership behaviors.

The findings corroborate previous research outcomes demonstrating that the positive relationship between coach leadership and both satisfaction and cohesion varies according to player sex (Kim and Cruz, 2016, 2022). Notably, in the current study, the influence of coach leadership on satisfaction and cohesion for both male and female athletes appears more pronounced than in the earlier systematic review. In the previous meta-analysis study, Kim and Cruz (2016) observed ESs for the leadership-satisfaction in male and female athletes were 0.424 and 0.174, respectively. Whereas the ES for the leadership-cohesion relationship was 0.193 for male players and 0.174 for female players. Variations in study samples may have contributed to the disparities in the results between these studies, with the previous study primarily composed of studies conducted in western countries. This finding implies that there are notable sociocultural variations in how athletes perceive the behaviors exhibited by their coaches and how these behaviors impact athletes' sport-related outcomes, as well as provides additional support that athletes' culture or nationality as an important antecedent of leadership.

4.4 Relationship between coach leadership and athlete satisfaction and cohesion based on player classification

Results revealed that the positive association between coach leadership and satisfaction levels is stronger among professional athletes than among their amateur counterparts (ES = 0.544 vs. ES = 0.215). A previous study indicated that elite athletes prefer more democratic and social support behaviors than club athletes. Conversely, club athletes favored coaches who often display rewarding behavior, a pattern observed less frequently among elite players (Terry, 1984). Another study found that athlete satisfaction varied between senior and junior levels, with senior athletes reporting greater satisfaction when perceiving coaches as frequently providing training and instruction, as well as social support behaviors (Ntomali et al., 2017). In this context, when Chinese coaches adapt their behavior appropriately, aligning with the preferences of the athletes, satisfaction is more likely to develop. This alignment supports the notion that athlete satisfaction is linked to congruence between leader behaviors and athlete preferences (Riemer and Toon, 2001; Kao et al., 2015). It further supports the MMSL framework, which posits that athlete sport-related outcomes (i.e., satisfaction) depend on the dynamics between leader behavior and antecedent conditions (Chelladurai, 2007).

The relationships between coach leadership and group cohesion, as well as its subgroups, demonstrated positive correlations, yielding similar moderate ESs for both amateur and professional players. These results suggest that coaching behaviors, as defined by the LSS scale, can moderately influence athletes' perceptions of cohesion, regardless of whether the players participate at the amateur or professional level. The similar effect sizes for the leadership-cohesion relationships based on sport classification may have resulted from the sample participants who are mostly team sport players representing particular geographical areas or state-sponsored sport schools. As previously mentioned, Chinese athletes generally enter sports schools at a very young age and spend their lives mastering sport-related knowledge and skills with the goal to participate in sport competitions and achieve sporting success. For example, professional athletes are those who are selected and trained by local teams with a primary goal to participate in city games, provincial games, national games, and other institutional competitions. They are fully supported by the state and relatively stable in terms of membership. Professional athletes also receive wages while their competition and training expenses are backed by the government. In this case, it is possible that Chinese athletes, regardless of sport classification, are likely to perceive higher level of cohesion due to similarities in competitive environment, group norms, group tasks, attitudes, cognition, and motives with regard to their athletic participation. This notion supports not only the MMSL model (Chelladurai, 2007) but also Carron (1982) which suggests that aside from leadership factors (i.e., leadership behaviors), task and social cohesion can result from environmental, personal, and team factors. Hence, the present findings highlight that better coach leadership is related to better cohesion in both amateur and professional athletes. Therefore, coaches should not only focus on leadership strategies that would enhance task cohesion among athletes, but also introduce interventions that promote compatibility and interpersonal closeness between leader and members.

Generally, the findings underscore the significant roles of player sex and classification in elucidating the relationship between coach leadership and athlete satisfaction and group cohesion. Furthermore, the current results enrich the sports leadership literature by synthesizing pertinent studies and performing a meta-analysis on the impact of coaches' leadership behaviors on athletes' sport-related outcomes within the Chinese context.

4.5 Limitations and future directions

This meta-analysis investigated only coaching behaviors and their effects on athlete satisfaction and group cohesion within the Chinese context. Consequently, the findings are generalizable solely to this population. Therefore, further research must be conducted on coach leadership and sport-related outcomes among athletes from diverse countries. Should sufficient studies become available, aggregating and categorizing the data by country could yield a more accurate understanding of whether the dynamics of coach leadership and sport-related outcomes are consistent across various national or cultural contexts, or if unique factors may influence the generalizability of the results.

Another limitation is the restriction of the measurement tool to the five dimensions defined in the LSS scale. Given that the LSS scale is the widely used tool in evaluating leadership of sport coaches based on the MMSL model, it is just appropriate to use this leadership measurement scale. Moreover, researchers examining coaches' leadership in the context of Chinese sports generally employed this measurement tool in their studies, and in turn, produced adequate number of articles to conduct meta-analysis Consequently, inferences about the impact of coaching behaviors on athlete satisfaction and cohesion might differ if alternative tools were used to evaluate coaches' leadership. Therefore, consolidating sports leadership studies that have utilized other prominent scales, such as the Coaching Behavior Scale for Sport (Côté et al., 1999), Multifactor Leadership Questionnaire (Bass and Avolio, 1997), and Differentiated Transformational Leadership Inventory (Callow et al., 2009) would be beneficial. This would provide better insights into which leadership styles and behaviors are more effective in fostering positive outcomes among athletes, beyond those assessed by the LSS scale or if the type of measurement tool acts as a moderator between the leadership-athlete satisfaction and team cohesion relationships.

4.6 Practical implications

Based on the findings of the study, for Chinese athletes to feel more satisfied with their athletic experiences as well as to perceive that their team are united in achieving their sport goals and objectives, and consequently lead to successful sport performance, Chinese coaches should display positive leadership behaviors that are also congruent to the personal characteristics of the players. For example, coaches of team sports in China dealing with female as well as elite (professional) athletes should frequently provide detailed and high-quality instructions focused on physical and mental development based on athletes' specific positions within the team. Game strategies should also be properly explained to the team and make sure that these strategies are extensively practiced to attain a high level of mastery. In this way, team players would be able to execute the appropriate movement patterns quickly and accurately against their opponents in sport competitions.

Offering feedback that is both motivational and instructional is another leadership behavior that coaches should consider implementing when interacting with athletes. This feedback should focus on providing quality information, such as describing performances that meet set standards successfully or identifying movement skills or behaviors that athletes themselves also acknowledge as needing modification for their athletic development. This leadership approach when properly provided to athletes during training and competitive situations, and at the same time recognized by athletes to be relevant and helpful for their athletic improvement is likely to increase athletes' positive emotions, leading to positive consequences such as enhanced motivation, competence, satisfaction and performance (Allen and Howe, 1998; Carpentier and Mageau, 2016; García-Herrero et al., 2022).

Meanwhile, as the present findings showed autocratic behavior to negatively impact both task and social cohesion, Chinese coaches should avoid controlling behaviors or create a training environment that is too rigid and structured. For example, despite the highly competitive nature of Chinese sports and the expectation for athletes to achieve performance success, coaches need to demonstrate flexibility in exercising their authority based on the competitive season or situation. For instance, Driscoll (2000) reported that

successful team athletes expected their coach to be authoritative to maintain their focus, direction, and intensity. It was also observed that athletes acknowledged that coach yelling was acceptable during practice, especially when team members' efforts were below par. In contrast, constant yelling and screaming by coaches at athletes during game situations were perceived as undesirable and ineffective coaching behavior. Hence, coaches should be mindful of the training and competitive situations when displaying autocratic behaviors toward athletes because these may facilitate or undermine levels of team cohesion.

5 Conclusion

This meta-analysis revealed that athletes' sport-related outcomes, particularly athlete satisfaction and group cohesion, can be shaped by the leadership behaviors of their Chinese coaches. Specifically, leadership behaviors that emphasize training and instruction, positive feedback, social support, and democratic decision-making are associated with moderate to high levels of satisfaction and group cohesion among Chinese athletes. Conversely, autocratic behaviors displayed by Chinese coaches may slightly increase athlete satisfaction but negatively impact group cohesion. Additionally, leadership behaviors of Chinese coaches are linked to higher satisfaction levels among female and amateur athletes compared to male and professional athletes. Moreover, these leadership behaviors positively and moderately influence group cohesion for both male and female players, as well as amateur and professional athletes. Consequently, for Chinese coaches to be effective sports leaders, they should exhibit diverse coaching behaviors that align with the players' characteristics and the sport's sociocultural environment.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation. Requests to access these datasets should be directed to JZ, 5418@zut.edu.cn.

Author contributions

JZ: Software, Resources, Formal analysis, Writing – review & editing, Writing – original draft, Conceptualization. MW: Software, Resources, Writing – review & editing, Formal analysis. AC: Writing – original draft, Conceptualization, Writing – review & editing. H-DK: Supervision, Writing – review & editing, Writing – original draft, Software, 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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1385178/full#supplementary-material

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EDITED BY
Carla Maria Chicau Costa Borrego,
Polytechnic Institute of Santarém, Portugal

REVIEWED BY
Fernando Jorge Santos,
Instituto Politecnico de Setubal (IPS), Portugal
Henri Tilga,
University of Tartu, Estonia

*CORRESPONDENCE
Felix Kruse
✉ felix.kruse@phsg.ch

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Longitudinal effects of basic psychological need support on the development of intrinsic motivation and perceived competence in physical education. A multilevel study

Felix Kruse[1]*, Sonja Büchel[2] and Christian Brühwiler[3]

[1]Institute of Physical Education, Sports and Health, St. Gallen University of Teacher Education, St. Gallen, Switzerland, [2]Institute of Education and Professional Studies, St. Gallen University of Teacher Education, St. Gallen, Switzerland, [3]Vice-President's Office for Research and Development, St. Gallen University of Teacher Education, St. Gallen, Switzerland

Background: Grounded in self-determination theory, this article deals with a multidimensional measurement of the support of the basic psychological needs and the individual and combined effects on the development of intrinsic motivation and perceived competence in physical education. In addition to the supportive teacher behaviors of autonomy support, competence support and relatedness support, peer relatedness support is examined as an additional factor.

Methods: A total of 1,047 students from 72 classes from various German-speaking Swiss cantons took part in the study. The hypothesized four factorial structure was analyzed using multilevel confirmatory factor analyses. Longitudinal measurement invariance testing of intrinsic motivation and perceived competence indicates scalar measurement invariance. Multilevel regression analyses were specified to analysis the longitudinal effects on the development of intrinsic motivation and perceived competence, whereby both the effects of the individual factors as well as the adjusted effects under the inclusion of all predictors were examined.

Results: Results of multilevel confirmatory factor analysis indicate that the hypothesized four-factor model (e.g., CFI = 0.97; TLI = 0.96; RMSEA = 0.04; SRMR between = 0.11) is to be favored over alternative models at both levels. Regarding the prediction of the development of intrinsic motivation and perceived competence our study underlines the predictive value of basic psychological need support. The models that examine the effects of the individual predictors indicate that the effects are largely consistent with expectations at both the class and individual level. At class level, however, autonomy support appears to be no significant predictor for the development of intrinsic motivation ($p < 0.10$), but for perceived competence ($p < 0.05$). Peer relatedness support is a significant predictor for both outcome variables at both levels of analysis. Regarding the simultaneous integration of all predictors, only the effects of peer relatedness support remain significant for both outcome variables.

Discussion: The empirical support of the multidimensionality of the instrument is particularly interesting in the context of the common conceptualization of a unidimensional measurement of autonomy support or a composite factor of

psychological need support, whereby only few studies have adequately tested the factorial validity. Although significant effects of supportive teacher behaviors can be demonstrated in the multilevel regression analyses, it is also indicated that the different dimensions lack of incremental predictive validity. Particularly noteworthy is the rarely investigated role of peer relatedness support, which has been shown to be a meaningful predictor, even when supportive teacher behaviors are taken into account.

KEYWORDS

basic psychological needs, self-determination theory, need support, physical education, MSEM, intrinsic motivation, perceived competence, autonomy support

1 Introduction

Motivation is one of the dominant topics in the field of sports psychology and it's contexts like physical education (PE) (Lindahl et al., 2015). This is hardly surprising, as participation and learning success in PE is characterized by a strong motivational component (Chatzisarantis and Hagger, 2009; Ntoumanis and Standage, 2009), which should ultimately also be evident in the context of life-long sports participation (Telama, 2009). PE offers a unique opportunity for children and adolescents to participate in sport and physical activity by not only becoming physically active during school hours, but also gaining the necessary skills and motivation to become physically active outside of school (Taylor et al., 2010; Shen, 2014; Vasconcellos et al., 2020). The relevance is striking, as the already insufficient physical activity decreases from childhood through adolescence (Dumith et al., 2011; Corder et al., 2019), despite being associated with a number of health conditions, such as cardiovascular or metabolic health as well as mental and cognitive health (Janssen and LeBlanc, 2010; Poitras et al., 2016; Biddle et al., 2019; Whooten et al., 2019). Regarding ongoing participation in physical activity into adulthood, the contribution of affective experiences in PE can be emphasized (Ladwig et al., 2018). Enjoyment and the perception of physical competence can be considered as particularly important in this regard as well as regarding the drop out of organized sports in children and youth (Stodden et al., 2008; Crane and Temple, 2015).

Self-determination theory (SDT) has proven to be a potent framework for describing the development and effects of motivation in this context. SDT's organismic integration theory differentiates between different types of motivation along a continuum from amotivation (a lack of motivation) to intrinsic motivation (e.g., students develop a genuine enjoyment or interest in PE; Ryan and Deci, 2017). For PE, beneficial associations of intrinsic motivation with adaptive outcomes such as physical activity intentions (Vasconcellos et al., 2020) as well as with an increase in physical activity levels (Lonsdale et al., 2019) have been demonstrated. Embedded in SDT, the theory of the three basic psychological needs emphasizes that for the development of high-quality motivation and the best possible functioning of oneself, the basic needs of autonomy, competence and relatedness must be satisfied. Autonomy can be understood as the perception of willingness of one's own experiences and actions. Competence is defined as the sense of effectiveness and mastery in interacting with the world, whereas relatedness is understood as connectedness with meaningful others, satisfaction with the social world and the feeling of being accepted (Ryan and Deci, 2017). Research could demonstrate that the satisfaction of these basic psychological needs is vital for personal growth, well-being and the development of autonomous motivation (Jang et al., 2009; Vasconcellos et al., 2020). Furthermore, a large number of studies have shown that the satisfaction of these basic psychological needs can be promoted by supportive environments (e.g., Roth et al., 2007; Vasconcellos et al., 2020). As social agents, PE teachers as well as peers have the potential to be supportive factors regarding the satisfaction of basic psychological needs and ultimately intrinsic motivation and well-being during PE class (Cheon and Reeve, 2013; White et al., 2021). Need-supportive teacher behaviors include the support of autonomy in, e.g., respecting student's attitudes and suggestions, providing meaningful rationale and giving choice (Lonsdale et al., 2019), competence support, which refers to teachers' provision of guidance on student performance to fosters their perception of competence and the feeling to be capable of successfully carrying out own endeavors (Sanchez-Oliva et al., 2014; Sparks et al., 2017), and relatedness support, which refers to the feeling of being understood by significant others and feeling connected to them. With regard to teachers, relatedness supportive teacher behaviors can involve devoting time to the students, reflecting the emotional needs of the students in the relationship with the teacher, and treating the students in an appreciative and warm manner (e.g., Sparks et al., 2017). Indeed, need supportive teacher behaviors have been shown in a large number of studies to promote, e.g., autonomous motivation, skill development and future intentions to exercise (Cheon et al., 2012; Sanchez-Oliva et al., 2014; Behzadnia et al., 2018).

In addition to teachers, peers can also be identified as important social agents in PE (e.g., Gairns et al., 2015). The term peer relatedness support can be understood as supportive aspects that refer to the satisfaction of relatedness by peers. In contrast to the need supportive behaviors of teachers, peer relatedness support has only been considered in a few studies (Vasconcellos et al., 2020). In addition, teachers and peers have mostly been studied in isolation (Gairns et al., 2015). Despite this limited attention to peer relatedness support, previous studies emphasize that there are associations with greater autonomous motivation and a reduction in anxiety in PE (e.g., Cox et al., 2009, 2011). Teachers and peers presumably have different ways of influencing potential positive outcomes. For example, it can be assumed that autonomy support is largely provided by the teacher, as they are to be understood as a higher authority in the classroom and can therefore influence the autonomy of the students to a greater extent. The same applies to competence support in that the feedback also largely originates from the teacher, so that s/he is able to influence the students' perceived competence to a greater extent

(e.g., Koka, 2014; Vasconcellos et al., 2020). In contrast, relatedness can likely be understood as being stronger influenced by peers, as they interact with each other on a broader scale throughout the day, rather than just during, e.g., PE class (Vasconcellos et al., 2020).

Vasconcellos et al. (2020) were further able to show in their recent meta-analysis that most of the evidence regarding social contexts and constructs of SDT can be found in the area of autonomy support. Almost three times as many studies have examined the teacher's autonomy support compared to competence or relatedness support. Regardless of the SDT's theoretical presumption that all psychological needs are deemed essential for an individual (Ryan and Deci, 2017), a unidimensional approach was mostly used when it comes to supportive factors, which focused solely on autonomy support (Su and Reeve, 2011; Sanchez-Oliva et al., 2014). This may be reasonable, as SDT postulates that all psychological needs are promoted by autonomy support (Ryan and Deci, 2017). In this context, however, it must be emphasized that autonomy support is understood in many operationalizations as an integrative term of an overall need supportive teacher behavior, including competence and/or relatedness support. Only few studies have examined need supportive teacher behaviors in PE in the context of a multidimensional approach, encompassing autonomy support, competence support and relatedness support as individual dimensions (Sanchez-Oliva et al., 2014; Ahn et al., 2019).

Therefore, the purpose of the present study is, firstly, to investigate the individual and combined effects of need supportive teacher behaviors on the development of students' intrinsic motivation and perceived competence and, secondly, to integrate peer relatedness support as an additional dimension. As mentioned, only few studies have investigated the multidimensionality of basic psychological need support in PE. Moreover, only few studies have analyzed need supportive behaviors in a multilevel context, ignoring the nested data structure, which can lead to biased results (Lüdtke et al., 2009; Huang and Cornell, 2016). However, intra-class correlations (ICC1) indicate a substantial amount of variance between classes of 19% of a composite need support scale (Ahn et al., 2021) as well as for relatedness support (Leo et al., 2023), demonstrating that multilevel modeling is indicated. The study by Ahn et al. (2019) is the only example we are aware of that addresses both the multidimensionality of need support and the clustered data structure. Taking up this desideratum, the authors conducted multilevel factor analyses (MEFA, MCFA) with the popular short version of the TASCQ. The frequently used composite or latent scores (e.g., Van Den Berghe et al., 2015; Ahn et al., 2021) of need supportive teacher behaviors were also emphasized in the study by Ahn et al. (2019), in that a unidimensional factor structure best represented the data. These findings raise the question if this unidimensional factor structure of need supportive teacher behaviors in PE can also be transferred to other instruments. Indeed, there are clear differences in the operationalization of the constructs, which suggest a more or less pronounced distinctiveness of the dimensions with regard to the item content. An example of this is the PE-adapted version of the Learning Climate Questionnaire (Standage et al., 2005), in which item formulations such as "we feel understood by our PE teacher" or "the PE teacher shows confidence in our abilities to do well in PE" were subsumed under autonomy support instead of relatedness or competence support. A three-dimensional factor structure appears less suitable for corresponding instruments than composite or latent scores. In our opinion, an approach that attempts to investigate the independent influence of the different need supportive teacher behaviors should have a correspondingly clear conceptual distinction of the constructs. Furthermore, we extend this statement to include the construct of peer relatedness support, which potentially has a unique explanatory power on students' intrinsic motivation and perceived competence and represents a promising area of research due to the limited recognition so far (Vasconcellos et al., 2020). Accordingly, the present study aims to examine the factorial structure of the basic psychological need support as well as the effects on intrinsic motivation and perceived competence on both the individual and class level.

Moreover, a special characteristic of the present study is the focus on changes in intrinsic motivation and perceived physical competence in individual sports. In this context, the exercise and self-esteem model (EXSEM) emphasizes that confidence in one's abilities in specific sport-related activities can be generalized to a broader perceived physical competence (Sonstroem et al., 1994). Furthermore, this approach is intended to enable the most action-proximal and most realistic representation of PE lessons, which are largely realized in the context of specific sports. It is assumed that a positive motivational development as well as perceived competence in specific sports can be transferred to PE in general but enables to a more fine-grained resolution of the support of the students in a particular teaching series. Consequently, the following research questions are addressed:

1 To what extent does the four-factor model of the basic psychological need support, including autonomy support, competence support, teacher relatedness support and peer relatedness support, adequately represent the data at individual and class level using multilevel confirmatory factor analysis? We hypothesize that a latent factor model with four individual- and class-level dimensions will provide the best fit to the data. (H1)
2 How does the students' perception of the basic psychological need support influence the development of intrinsic motivation in basketball at the individual and class level? We assume that all four factors are significant predictors for intrinsic motivation at both the individual and class level. With regard to supportive teacher behaviors, we assume that autonomy support in particular acts as a meaningful predictor. Furthermore, we assume that peer relatedness support explains an independent part of the variance. (H2)
3 How does the students' perception of the basic psychological need support influence the development of perceived competence in basketball at the individual and class level? We assume that all four factors are significant predictors for perceived competence at both the individual and class level, whereby it is hypothesized that autonomy and competence support represent stronger predictors than teacher relatedness support. Furthermore, we assume that peer relatedness support explains an independent part of the variance. (H3)

2 Materials and methods

2.1 Study design and participants

Data stems from the EPiC-PE study (Messmer et al., 2022), which aims to investigate the effects of professional competencies of PE

teachers on instructional quality and students´ outcomes. The analysis of the factor structure involved 1,047 students from 72 seventh- through ninth-grade classes. While for research question 1 the full data set could be used, for research question 2 and 3 we used a subsample of 735 students from 49 classes which also participated in the analysis of the longitudinal effects on intrinsic motivation and perceived competence in basketball.[1] Secondary schools in several German-speaking Swiss cantons were contacted in order to recruit participants. Data collection took place between October 2021 and April 2022. The study involved two measurement points with a teaching series of 12 lessons between them. The completion time for the entire survey section took 15–20 min at each measurement point and was supplemented by a knowledge test. Beforehand, the students received a short explanation from their physical education teacher, who was trained for this purpose by means of a standardized written explanation. Parents were informed prior that participation was voluntary and were required to sign an informed consent form. Students were also informed that participation was voluntary. No incentives were given for participation. The teachers had to complete their own questionnaire and were present during the entire assessment. Teachers were given motor goals (e.g., "Students will be able to dribble a ball safely and shielded around obstacles") from the swiss PE curriculum to achieve in the 12-lesson teaching series. In general, the teachers were supposed to realize their lessons in such a way that they led to the achievement of the corresponding goals. The teaching was conducted without further instruction, so that the variance in support of the basic psychological needs can be attributed as much as possible to the actual, natural performance of the teachers. Students rated perceived need support at the second measurement point, referring to the teaching series, so that the assumption seems to be more plausible, that the perceived need support is causally prior to the outcomes (Naumann et al., 2020). Intrinsic motivation and perceived competence in basketball were assessed via repeated measures directly before and after the teaching series, so that an investigation of the development becomes possible. The average class size for the sample is 14.5 students per class. The average age of students drawn from grades seven to nine is 14.5 years (SD = 1.6). Forty-seven percent of the subjects were female.

2.2 Measures

Intrinsic motivation for basketball was assessed by a scale consisting three items (e.g., "Basketball is fun for me") adapted from Büchel (2019). Perceived competence in basketball was assessed by a scale also comprises three items (e.g., "I'm very good at basketball") adapted from (Gerlach, 2008). Need supportive teacher behaviors and peer relatedness support were assessed, adapting the items from the COACTIV and Pythagoras study (Baumert et al., 2009; Rakoczy et al., 2013). Before completing the items, the students were given the following instruction: "To what extent do you agree with the following statements about your physical education class and your physical education teacher in the last teaching series?." Perceived autonomy support contained four items (e.g., "In my PE class, I have the opportunity to explore new movements independently"), competence support also contained four items (e.g., "In my PE class, it is recognized when I accomplish something"), teacher relatedness support contained three items (e.g., "Our PE teacher takes care of the students' problems") and peer relatedness support contained four items (e.g., "In our PE class, I am treated as a friend by the others in the class"). All variables were completed on a Likert scale from 1 (totally disagree) to 4 (totally agree).

2.3 Analyses

The factorial structure was analyzed via multilevel confirmatory factor analysis (MCFA) that was specified doubly latent accordingly to the approach of Marsh et al. (2009). We compared the hypothesized four-factor structure with alternative models. In the next step, we analyzed longitudinal measurement invariance of intrinsic motivation and perceived competence to disentangle whether the observed differences in the two variables are due to a true individual difference in means or whether they are structural differences (Miyamoto et al., 2020). Three levels of measurement invariance with different numbers of model parameters were conducted, starting with configural measurement variance, followed by metric and scalar measurement invariance (Chen, 2007). Two correlated factors (T1, T2) were specified in the configural invariance model. Factor means were fixed to 0, factor variances were fixed to 1 for model identification and the co-variances and residual co-variances of the same indicators were freely estimated across the two measurement points. In the metric measurement invariance model, the factor variances were fixed to 1 for model identification at T1 and freely estimated for T2, and the factor loadings were constrained to be equal over time. Finally, the scalar measurement invariance model was tested to examine a significant comparison of means over time, in which the intercepts were additionally constrained to be equal over time. To examine the prediction of the need supportive practices on the development of intrinsic motivation and perceived competence, doubly manifest multilevel regression analyses were specified, with single manifest indicators for the scales and a manifest aggregation of the level 1 units at the class level (Marsh et al., 2009). Group mean centering (Lüdtke et al., 2009) for level 1 variables of supportive practices was used. Gender was introduced as a manifest covariate at the within level.

All models were estimated using Mplus 8.7 (Muthén and Muthén, 2017) with robust Maximum Likelihood estimation (MLR), which is robust against non-normality of item responses. Despite the categorical variables, we preferred MLR estimation over weighted least squares means and variance adjusted (WLSMV) estimation, following the practice of Aguado et al. (2015). In this context we specify at least four response options on a frequency scale (Beauducel and Herzberg, 2006) and we can use the "missing at random" (Asparouhov and Muthén, 2010) handling of missing data. Goodness-of-fit was assessed using the absolute fit indices, adhering to conventional cutoff values from Hu and Bentler (1999): standardized root mean square residual (SRMR) ≤ 0.08; root mean square error of approximation (RMSEA) ≤ 0.06; comparative fit index (CFI) and tucker-lewis index (TLI) ≥ 0.95 as well as χ^2 /df-Ratio (Wheaton et al., 1977). The proportion of missing values per item was between 0.0 and 1.4%. Missing values were addressed using the full information maximum likelihood estimator (FIML).

1 The teaching series was carried out in the area of invasion games using basketball and handball as examples. Due to the consistently strong emphasis (>80%) on basketball, the analyses only focus on basketball.

3 Results

Descriptives (Tables 1, 2) indicate good to very good reliability of the scales. An increase in the observed mean value of intrinsic motivation and perceived competence can be found between the two measurement points, which is particularly evident in the case of perceived competence. Intraclass correlation coefficients (ICCs) as well as design effects indicate substantial dependence of clustering of the data within classes. In this context ICC1 values higher than 0.05 indicate meaningful correlations of variables between and within. ICC2 values higher than 0.60 indicate a meaningful aggregation of the individual-level data on the class level (Bliese, 2000; Chen et al., 2004). Only peer relatedness support showed ICC2 values that were slightly below the cut-off, indicating insufficient reliability of the scale at the class level.

3.1 Research question 1: factor structure

To address research question 1, we examined the factor structure of the basic psychological need support using MCFA (Table 3). First, we tested a unidimensional solution of an overall need supportive environment, which showed a poor model fit. A model with two factors, in which need supportive teacher behaviors and peer relatedness support were specified as separate factors, showed a better, but still insufficient model fit. In the next step, we compared different models with three factors, which encompass different ways of combining individual dimensions of need supportive teacher behaviors, whereas peer relatedness support was still specified as an independent factor. These models indicated a further improvement in model fit. However, the hypothesized model with four factors showed a considerably better model fit, which was completely satisfactory in the context of conservative fit statistics at the individual level (Hu and Bentler, 1999). The SRMR between, for which it is difficult to state cut-off values as sample sizes in multilevel models often tend to have less than 200 clusters (Asparouhov and Muthén, 2018), was also in a comparatively good range at 0.11. Table 4 presents the inter-factor correlations at individual and class level with respect to the hypothesized four factor structure, ranging from $r = 0.47$ to $r = 0.75$ at individual level and $r = 0.45$ to $r = 0.92$ at class level. The overall correlational pattern is in line with expectations, being higher between conceptual closer dimensions at both levels. All factor loadings were found to be statistically significant. On the individual level, standardized factor loadings for all items ranged from $\lambda = 0.69$ to $\lambda = 0.85$, while on the class level, factor loadings ranged from $\lambda = 0.67$ to $\lambda = 1.00$. Two heywood cases appeared at the class level, in which the only minor negative residual variances were fixed to zero (Hox et al., 2017).

3.2 Research question 2 and 3: prediction of intrinsic motivation and perceived competence

3.2.1 Measurement invariance

Table 5 shows the results of the longitudinal measurement invariance testing of intrinsic motivation and perceived competence. The results of the models regarding conservative fit statistics show that the models with three indicators each exhibit scalar measurement invariance. This indicates that the structure remained the same across the two measurement points and that a comparison of the mean values can be justified. Another interesting finding relates to the latent mean difference over time, which is significant for both variables (intrinsic motivation = 0.11, $p = 0.00$; perceived competence = 0.26, $p = 0.00$).

3.2.2 Intrinsic motivation

After the longitudinal measurement invariance was tested, we continued with the multilevel regression analyses. Table 6 shows the stepwise analysis of the inclusion of individual predictors (M1-M5) and the simultaneous consideration of all predictors in one model (M6). First of all, it can be noted that motivation at T1 is a strong predictor at both levels for motivation at T2. Furthermore, gender is also a significant predictor at the individual level. With regard to the separate integration of need support dimensions, only autonomy support and peer relatedness support can be identified as significant predictors for the development of intrinsic motivation at the individual level. Competence support and teacher relatedness support do not represent significant predictors. Only the effect of peer relatedness support also remains in Model 6 when all predictors are considered together. At the class level, in the separate integration of the need support variables, competence support, teacher relatedness support and peer relatedness support are significant predictors, whereas autonomy support represents no significant predictor ($p < 0.067$). However, due to the small number of clusters, we have also provided values at the class level at the $p < 0.10$ significance level. Regarding the simultaneous analysis of all predictors in M6, only the peer relatedness support remains significant, analogous to the individual level. The predictors in M6 explained 48% of individual-level variance and 66% of between-level variance in students' intrinsic motivation at T2.

TABLE 1 Descriptives: basic psychological need support.

Item example (1 = not true at all; 4 = exactly true)								
Factor	Items	("In our physical education class..."; "Our physical education teacher...")	*M*	SD	α	ω	ICC1	ICC2
Autonomy support	4	I have the opportunity to explore new movements independently.	2.93	0.65	0.82	0.82	≥0.10	≥0.62
Competence support	4	It is recognized when I accomplish something.	2.99	0.66	0.86	0.86	≥0.13	≥0.75
Teacher relatedness support	3	Takes care of the students' problems.	3.12	0.70	0.84	0.84	≥0.17	≥0.68
Peer relatedness support	4	I feel understood by the other students in the class.	3.23	0.71	0.90	0.90	≥0.09	≥0.59

TABLE 2 Descriptives: intrinsic motivation and perceived competence.

Factor	Items	Item example (1 = not true at all; 4 = exactly true)	*M*	SD	α	ω
Intrinsic motivation T1	3	Basketball is fun for me.	2.73	0.84	0.94	0.94
Intrinsic motivation T2	3	Basketball is fun for me.	2.83	0.82	0.93	0.93
Perceived competence T1	3	I'm very good at basketball.	2.47	0.66	0.86	0.86
Perceived competence T2	3	I'm very good at basketball.	2.7	0.59	0.82	0.82

TABLE 3 Doubly latent multilevel confirmatory factor analysis of basic psychological need support.

	χ^2	*df*	χ^2/df	CFI	TLI	RMSEA	SRMR within	SRMR between
Hypothesized model								
4-factor model	429	179	2.39	0.97	0.96	0.04	0.03	0.11
Alternative models								
3-factor model (AS & CS as one Factor)	726	186	3.90	0.93	0.92	0.05	0.04	0.12
3-factor model (AS & TRS as one Factor)	936	186	5.03	0.90	0.89	0.06	0.05	0.14
3-factor model (CS & TRS as one Factor)	943	186	5.07	0.90	0.89	0.06	0.05	0.12
2-factor model (AS,CS,TRS as one Factor)	1,213	191	6.35	0.87	0.85	0.07	0.06	0.14
1-factor model	2,597	194	13.38	0.68	0.66	0.11	0.1	0.23

AS, autonomy support; CS, competence support; TRS, teacher relatedness support.

However, need support at the individual level only explained additional 1% of variance, while at class level 11% of variance could be explained.

3.2.3 Perceived competence

With regard to the prediction of perceived competence at T2, perceived competence at T1 was a strong predictor at both levels. As for intrinsic motivation, gender was a significant predictor for the development of perceived competence at the individual level. With regard to the separate consideration of individual need support variables, all predictors except teacher relatedness support were significant at the individual level. Peer relatedness support represents again the strongest predictor. The simultaneous consideration of all predictors in one model (M6) showed, similar to intrinsic motivation, that peer relatedness support remains the only significant predictor when the other need support variables are taken into account. At the class level, all four need support dimensions were significant predictors, with autonomy and competence support being the strongest. However, when all predictors in M6 were considered simultaneously, only peer relatedness support remains significant. Also in this case, due to the small number of clusters, we have provided values at the class level at the $p < 0.10$ level, in which autonomy support acts as a significant predictor ($p = 0.095$). The predictors in M6 explained 40% of individual-level variance and 52% of between-level variance in students' perceived competence at T2. Need supportive practices at the individual level explained additional 3% of variance, while at class level 19% of variance could be explained.

4 Discussion

Numerous research findings within and outside of physical education emphasize the importance of providing support for the three basic psychological needs. However, little attention has been paid to the individual and combined contributions of the different need support dimensions for positive motivational development and optimal human functioning. As Ryan and Deci (2017) note, the focus on autonomy support as a predictor of basic need satisfaction is in no way due to the idea that autonomy is more important than competence or relatedness. However, SDT postulates that autonomy support as a contextual factor is particularly significant when it comes to the active satisfaction of all individual's needs (Ryan and Deci, 2017). Against this background, only a few studies have investigated basic psychological need support in terms of multidimensionality. Likewise, only few studies have investigated peer relatedness support in physical education (Vasconcellos et al., 2020). Finally, there are hardly any research findings to date that take the clustered data structure into account using a multilevel approach, even though the support of the three basic psychological needs are characteristics of a learning environment. Derived from these desiderata, we proposed a four-factor structure that differentiates relatedness support into teacher relatedness support and peer relatedness support in addition to autonomy support and competence support and tested this model with regard to the factorial structure and the prediction of the development of intrinsic motivation and perceived competence at individual and class level within the context of a teaching series in physical education.

Our factor analytical results support the hypothesized four-factor model and thus the assumption that autonomy support, competence support, teacher relatedness support and peer relatedness support represent separate but highly correlated dimensions at both individual and class level. Different alternative models showed a poorer model fit (ΔCFI = −0.04; ΔTLI = −0.04; ΔRMSEA = +0.01; ΔSRMR within/between = +0.01). This finding is interesting in the context of previous studies that were unable to confirm a multidimensional structure (Ahn et al., 2019). One possible explanation lies in the heterogeneity of the conceptualizations and measurements of basic psychological needs support. A systematic analysis of different operationalizations and the associated factor

analytical results as well as the predictive evidence appears to be a worthwhile endeavor. Our approach corresponds to an operationalization with items that are clearly assignable. It is also interesting to note that the factorial structure also favors a four-factor solution at the class level, as a less differentiated number of factors is a common phenomenon (Dedrick and Greenbaum, 2011). Moreover, the high inter-factor correlations could indicate dependencies in the function of the individual variables (e.g., autonomy support as a prerequisite for teacher relatedness support).

With regard to the prediction of intrinsic motivation (Table 6) and perceived competence (Table 7), the results of the multilevel regression analyses were partially in line with our expectations. As assumed, the separate integration of individual dimensions of students' shared perceptions at the class level showed that supporting the basic psychological needs resulted in a positive development of intrinsic motivation. However, autonomy support could only be shown to be a substantial predictor at the $p < 0.10$ significance level. When all predictors were considered simultaneously, only the perceived support of relatedness by peers remained significant. At the individual level, it was also shown that students who felt more connected to their peers compared to their classmates and who perceived more autonomy and competence support compared to their classmates showed a positive motivational development.

TABLE 4 Inter-factor correlations at individual and class level.

Factor	AS	CS	TRS	PRS
AS	1	0.75**	0.60**	0.56**
CS	0.92**	1	0.62**	0.57**
TRS	0.89**	0.90**	1	0.47**
PRS	0.45**	0.47**	0.52**	1

AS, autonomy support; CS, competence support; TRS, teacher relatedness support; PRS, peer relatedness support. *p < 0.05. **p < 0.01.

TABLE 5 Longitudinal measurement invariance of intrinsic motivation and perceived competence.

Model	χ^2	*df*	*p*	CFI	TLI	RMSEA
Intrinsic motivation						
Configural invariance	42.05	8	0.00	0.99	0.98	0.08
Metric invariance	46.46	10	0.00	0.99	0.99	0.07
Scalar invariance	46.51	12	0.00	0.99	0.99	0.06
Difference between models	configural/metric: $\Delta\chi^2$ ($\Delta df = 2$) = 4.42, $p = 0.35$; metric/scalar: $\Delta\chi^2$ ($\Delta df = 2$) = 0.06, $p = 0.97$					
Perceived Competence						
Configural invariance	63.54	8	0.00	0.96	0.93	0.10
Metric invariance	68.44	10	0.00	0.96	0.95	0.09
Scalar invariance	68.59	12	0.00	0.96	0.96	0.08
Difference between models	configural/metric: $\Delta\chi2$ ($\Delta df = 2$) = 5.05, $p = 0.28$; metric/scalar: $\Delta\chi2$ ($\Delta df = 2$) = 0.15, $p = 0.93$					

TABLE 6 Doubly manifest multilevel regression analysis: intrinsic motivation.

	M1		M2		M3		M4		M5		M6	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
Within												
Motivation, T1	0.68*	0.03	0.67*	0.03	0.66*	0.02	0.67*	0.03	0.66*	0.03	0.66*	0.03
Gender	0.13*	0.05	0.13*	0.05	0.13*	0.05	0.13*	0.05	0.13*	0.05	0.13*	0.05
Autonomy support			0.06*	0.03							0.03	0.04
Competence support					0.06	0.04					0.03	0.05
Teacher relatedness support							0.03	0.03			−0.02	0.04
Peer relatedness support									0.08*	0.03	0.07*	0.04
R^2	0.47		0.48		0.48		0.48		0.48		0.48	
Between												
Motivation, T1	0.74*	0.07	0.69*	0.09	0.62*	0.10	0.64*	0.09	0.68*	0.08	0.59*	0.09
Autonomy support			0.17[a]	0.09							−0.11	0.15
Competence support					0.28*	0.11					0.22	0.24
Teacher relatedness support							0.26*	0.11			0.10	0.15
Peer relatedness support									0.29*	0.14	0.22*	0.09
R^2	0.55		0.58		0.61		0.61		0.63		0.66	

Standardized regression coefficients; *$p < 0.05$. [a]$p < 0.10$.

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TABLE 7 Doubly manifest multilevel regression analysis: perceived competence.

	M1		M2		M3		M4		M5		M6	
	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
Within												
Perceived Comp., T1	0.60*	0.04	0.58*	0.04	0.57*	0.04	0.59*	0.04	0.57*	0.04	0.56*	0.04
Gender	0.10*	0.04	0.11*	0.04	0.11*	0.04	0.11*	0.04	0.11*	0.04	0.11*	0.04
Autonomy support			0.08*	0.04							0.01	0.04
Competence support					0.11*	0.04					0.07	0.05
Teacher relatedness support							0.05	0.05			−0.03	0.05
Peer relatedness support									0.14*	0.03	0.12*	0.03
R^2	0.37		0.38		0.38		0.38		0.39		0.40	
Between												
Perceived Comp., T1	0.58*	0.14	0.49*	0.14	0.46*	0.15	0.49*	0.15	0.50*	0.11	0.43*	0.14
Autonomy support			0.39*	0.13							0.32[a]	0.19
Competence support					0.37*	0.13					0.06	0.24
Teacher relatedness support							0.32*	0.14			−0.04	0.17
Peer relatedness support									0.30*	0.14	0.23*	0.09
R^2	0.33		0.48		0.46		0.43		0.42		0.52	

Standardized regression coefficients; *$p < 0.05$. [a]$p < 0.10$.

However, in the simultaneous analysis of all predictors, again, only peer relatedness support remained significant.

Similar findings were found for the development of perceived competence. At the class level, all four support dimensions were significant predictors. However, in contrast to intrinsic motivation, autonomy support was the strongest predictor, followed by competence support and peer relatedness support, in line with our second hypothesis. In the simultaneous analysis of all predictors, peer relatedness support was again found to have a unique predictive power, whereas autonomy support was significant only at the $p < 0.10$ significance level. At the individual level, it can be basically stated that students who perceived their teacher as more autonomy- and competence-supportive compared to their classmates, showed a positive development of perceived competence. Peer relatedness support also had a positive effect at the individual level, whereas only teacher relatedness support showed no effect. These findings are in line with expectations and correspond to the assumption outlined above that autonomy and competence support can be influenced by the teacher in particular. In the simultaneous analysis of all predictors, as with intrinsic motivation, only peer relatedness support remained significant. The unique predictive power of peer relatedness support is in line with our expectations (see H2), as a different group of reference is addressed. Nevertheless, it was expected that the support of autonomy would also remain significant. Therefore, these findings could indicate a lack of incremental predictive validity of the three dimensions of supportive teacher behaviors. Although this finding is congruent with the SDT's focus on autonomy support (Ryan and Deci, 2017) and the unidimensional modeling of supportive teacher behavior, a relatively strict separation of the three dimensions does not indicate that autonomy support is more meaningful with regard to intrinsic motivation.

These results should be viewed critically against the background of the parsimonious operationalization. Studies operationalize autonomy support in a very heterogeneous way, such as quite narrow as the merely provision of choice up to a very comprehensive multidimensional measurement (Stefanou et al., 2004; Zimmermann et al., 2020; Ahmadi et al., 2023). In our case, the instrument integrated a motivating component for autonomous work, the possibility of independent examination of the learning object, the provision of choice and openness to suggestions. In line with classification systems (Teixeira et al., 2020; Ahmadi et al., 2023), future research should critically reflect on the different operationalizations of the constructs and eventually reinterpret effects. However, in order to gain a better understanding of the mechanisms of action of the different need supportive behaviors, to design targeted interventions and to inform teacher practices, the multidimensional approach, investigating the individual contributions and the interaction of the different support dimensions in the promotion of motivational and competence-related outcomes, appears to be a worthwhile endeavor for future studies. In this context, tailoring educational strategies to meet students' needs by understanding various dimensions of need support could significantly enhance instructional efficacy. To provide appropriate support for each student and not to embody a controlling, cold or chaotic teaching style (e.g., Van den Berghe et al., 2013; Aelterman et al., 2019), simultaneous support for all needs seems essential. One possible explanation that these potential additive effects of basic psychological needs support aren't reflected in our data is that data originates from students' subjective perceptions. Against this background, the items refer to the rating of the teaching or the teacher and thus show clear parallels with research on instructional quality, in which the ability of students to sufficiently differentiate between different dimensions with conceptual overlap is critically reflected (e.g., Kruse et al., 2024). For example, an affective overall attitude in the sense of a halo effect across the individual dimensions could be present (e.g., Wallace et al., 2016; Röhl and Rollett, 2021). External observation studies would represent a more objective data source in this regard and could

be applied in future studies. Similar effects could be shown for student's engagement, where it could be demonstrated that in externally rated collective behavioral engagement an additional effect of autonomy support and structure was present, whereas there were small effects and no independent explanatory power of structuring over autonomy support in relation to self-reported individual engagement (Jang et al., 2010). Further important limitations are the relatively short survey period, in which effects were examined over a period of only six weeks. An investigation over a longer period would appear to be a valuable and complementary endeavor. A larger sample would be desirable for the use of multilevel structural equation modeling of the longitudinal data so that sample and measurement error can be addressed (e.g., Marsh et al., 2009).

Furthermore, it would be worthwhile to examine differential effects as well as the associations with related constructs that could potentially be significant for the perceived support of the three basic psychological needs, such as teachers' professional competence (Wittwer et al., 2023), teachers' continuing professional development (Büchel et al., 2023) or the satisfaction of the psychological needs (e.g., Vasconcellos et al., 2020) - both as an independent outcome and as a mediator for the development of intrinsic motivation. Finally, the findings highlight the role of peer relatedness support, which has received little attention in research so far (e.g., Vasconcellos et al., 2020). The results provide important evidence that peer relatedness support has a significant impact on both the intrinsic motivation and perceived competence of students. This underlines the need to specifically encourage peer interactions within PE lessons in order to create a supportive learning environment that is motivating and strengthens the perception of competence.

Data availability statement

The datasets presented in this article are not readily available because a data embargo is in place until the completion of qualification work within the context of the project by February 2025. Requests to access the datasets should be directed to the corresponding author, and from February 2025 on SWISSUbase.

Ethics statement

Ethical approval was not required for this study 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

FK: Formal analysis, Writing – original draft, Writing – review & editing. SB: Conceptualization, Writing – review & editing. CB: Conceptualization, 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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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Soukaina Hattabi,
University of Jendouba, Tunisia
Brendan SueSee,
University of Southern Queensland, Australia

*CORRESPONDENCE
Daliang Zhao
✉ zhaodaliang@tom.com

†These authors have contributed equally to this work and share first authorship

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Development of the Chinese coaches' autonomy-supportive—*laissez-faire* coaching style scale

Wen Su[1†], Liqin Wang[2†], Yingmin Ding[2†] and Daliang Zhao[1,3*]

[1]Public Courses Teaching Department, Guangzhou Sport University, Guangzhou, China, [2]Graduate School, Guangzhou Sport University, Guangzhou, China, [3]College of Leisure and Digital Sports, Guangzhou Sport University, Guangzhou, China

Introduction: The autonomy-supportive coaching style is recognized for its positive impact on athletes' well-being and performance. However, the transition of excessive autonomy into a *laissez-faire* coaching style has not been thoroughly examined within the context of coach evaluation scales. Existing scales focus predominantly on the positive dimensions of autonomy support, and do not possess the capabilities to measure outcomes which may be viewed as negative or other outcomes. This study aims to integrate the autonomy-supportive and *laissez-faire* coaching styles within the same measurement framework.

Methods: Our study developed a comprehensive scale to assess both the autonomy-supportive and *laissez-faire* coaching styles, drawing on items from the Sport Climate Questionnaire for autonomy support and adapting items from leadership research for *laissez-faire* coaching. We conducted two studies: the first with 148 athletes to refine the *laissez-faire* items and the second with 460 athletes to validate the full scale, utilizing exploratory factor analysis, confirmatory factor analysis, and correlation analysis. We also measured internal consistency and split-half reliability.

Results: The finalized scale includes a 6-item autonomy-supportive subscale and a 5-item *laissez-faire* subscale. Validation processes confirmed the scale's construct and criterion validity, alongside its reliability.

Discussion: The Chinese Coaches' Autonomy-Supportive—*Laissez-Faire* Coaching Style Scale effectively captures both the beneficial and potentially detrimental aspects of coaching styles, addressing a critical gap in the literature and providing a reliable tool for evaluating coaching approaches.

KEYWORDS

coaching style, autonomy-supportive coaching style, *laissez-faire* coaching style, coach evaluation scale, coaching style assessment

1 Introduction

Coach-related factors in the sport environment significantly impact athletes' growth and development (Côté et al., 2010). Researchers have found improvements in athletes' subjective vitality (Reinboth and Duda, 2006; Adie et al., 2012), well-being (Haerens et al., 2018), performance (Gillet et al., 2010; Lemelin et al., 2022), mental toughness (Mahoney et al., 2016), and persistence (Pelletier et al., 2001) linked to an autonomy-supportive coaching style.

Although an autonomy-supportive coaching style benefits athletes, some coaches express concern that their approach might blur the distinction between providing autonomy support and adopting a *laissez-faire* attitude during practice. This ambiguity arises from the conceptual overlap between the two coaching styles (Stolz and Pill, 2016; SueSee et al., 2021). An autonomy-supportive coaching style includes empathizing with athletes, acknowledging their feelings, and offering opportunities for action and decision-making (Stebbings et al., 2012; Rocchi et al., 2013). Moreover, a crucial skill in this coaching style is to listen carefully to players' responses, interpreting their significance or completeness (Pill et al., 2021a). By contrast, a *laissez-faire* coaching style is marked by decision-making avoidance, a lack of positive feedback and involvement, and permitting athletes to make their own choices and decisions (Skogstad et al., 2007; Hinkin and Schriesheim, 2008). It is worth noting that, although Self-Teaching Style K is not exactly the same, it shares some similarities. In both styles, the player takes on both the coach and learner roles, making all decisions about the subject matter and activities to achieve their goals (Pill et al., 2021b). However, while both autonomy-supportive and *laissez-faire* coaching styles allow athletes to make choices and decisions, they differ in the level of authorization (Wong and Giessner, 2018). Distinguishing between coaches who adopt an autonomy-supportive or a *laissez-faire* coaching style is crucial for understanding their effectiveness and impact on athlete development.

Despite the potential confusion between the autonomy-supportive and *laissez-faire* coaching styles, existing scales fail to differentiate between the two. The Sport Climate Questionnaire is the most widely used instrument to assess coaching style (Deci and Ryan, 2001); however, this scale measures only the autonomy-supportive dimension and does not include *laissez-faire*. More recently, Delrue et al. (2019) introduced a circumplex model of coaching styles, categorizing four coaching styles into eight more specific approaches: autonomy support (participative and attuning), structure (guiding and clarifying), control (demanding and domineering), and chaos (abandoning and awaiting). This research did not explore the relationship between the autonomy-supportive and *laissez-faire* coaching styles, even though these styles were incorporated into the framework. Additionally, the original *laissez-faire* leadership scale, part of the Multifactor Leadership Questionnaire (Bass and Avolio, 1996), forms the basis for most related scales in leadership styles but only evaluates *laissez-faire* leadership, omitting autonomy-supportive leadership.

This study aims to integrate the autonomy-supportive and *laissez-faire* coaching styles within the same measurement framework. Furthermore, the development of the Chinese Coaches' Autonomy-Supportive—*Laissez-Faire* Coaching Style Scale will provide coaches with a vital foundation for comprehending the degree of the autonomy-supportive coaching style in their practices.

2 Study 1

2.1 Methods

2.1.1 Participants

Study 1 encompassed 148 athletes from Guangdong Province, consisting of 77 men and 71 women, with ages spanning 13–30 years (M = 20, SD = 3.079). The distribution of age groups was as follows: 13–15 (n = 8), 16–20 (n = 87), 21–25 (n = 47), and 26–30 years (n = 6). Training experience ranged from 0–23 years (M = 6.66, SD = 4.033) and was categorized as 0–5 (n = 75), 6–10 (n = 49), 11–15 (n = 20), 16–20 (n = 3), and 21–23 (n = 1). Participants were involved in athletics (n = 100), martial arts (n = 39), and gymnastics (n = 9). The Institutional Review Board of Guangzhou Sport University approved all procedures. All participants or their guardians provided written informed consent.

2.1.2 Measures

The *laissez-faire* leadership subscale is adapted from the Multifactor Leadership Questionnaire (Bass and Avolio, 1996). A 7-item preliminary scale was formulated by integrating the *laissez-faire* leadership subscale with the sports environment (Avolio et al., 1999; Skogstad et al., 2007; Hinkin and Schriesheim, 2008; Xirasagar, 2008). A defining characteristic of the *laissez-faire* coaching style is inaction, as reflected in "My coach lets me handle training challenges independently." Responses were evaluated using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree).

2.1.3 Data collection and analysis

Data were collected online via the popular Chinese professional survey platform Wenjuanxing.[1] Following approval from the program center's head, athletes were given the link to complete the scale. SPSS 25.0 facilitated data analysis, including item-total and item-item correlation analyses for item elimination. Items with correlation coefficients with an overall score below 0.6 were excluded, alongside those with low correlation coefficients with other items.

2.2 Results

2.2.1 Item-total and item-item correlation analyses

Initially, the correlation coefficients between each item and the overall score of the *laissez-faire* coaching style subscale were evaluated. It was determined that no items needed to be removed after reviewing items with correlation coefficients less than 0.6. Subsequently, two items were identified for deletion based on the item-item correlation analysis results, specifically, "If I do not seek help from my coach, my coach will not offer assistance" and "My coach lets me handle training challenges independently." These items' correlation coefficients with other items consistently fell below 0.6. They were excluded to ensure dimensional consistency and relevance to the context of Chinese competitive sports.

3 Study 2

3.1 Methods

3.1.1 Participants

Study 2 involved 460 athletes from Guangdong Province, consisting of 239 men and 221 women, with ages ranging from 10–32 years (M = 18.78, SD = 3.763). The age groups were as follows: 10–15 (n = 90), 16–20 (n = 237), 21–25 (n = 111), 26–30 (n = 21), and 31–32 years (n = 1). Training experience ranged from 0–23 years

1 https://www.wjx.cn/

(M = 8.49, SD = 3.910) and was categorized as follows: 0–5 (n = 118), 6–10 (n = 223), 11–15 (n = 97), 16–20 (n = 20), 21–23 (n = 2). Participants engaged in various sports including fencing (n = 58), volleyball (n = 49), gymnastics (n = 45), badminton (n = 42), weightlifting (n = 29), swimming (n = 28), basketball (n = 28), table tennis (n = 28), sanda (n = 27), diving (n = 25), athletics (n = 23), artistic swimming (n = 20), trampolining (n = 20), Wushu (n = 19), water polo (n = 16), and tennis (n = 3). All procedures were approved by the Institutional Review Board of Guangzhou Sport University. All participants or their guardians provided written informed consent.

3.1.2 Measures

The autonomy-supportive subscale, initially derived from the health domain (Williams and Deci, 1996) was later adapted for the sports context. This scale measures athletes' perceptions of autonomy support from their coaches, exemplified by "I feel that my coach provides me with choices and options." The adjusted scale showed robust psychometric properties (Reinboth et al., 2004). A 7-point Likert scale was used to rate responses (1 = strongly disagree, 7 = strongly agree).

Study 2 implemented the Self-Esteem Scale and the Subjective Vitality Scale to validate the study's scale. The Self-Esteem Scale is known for its reliability in assessing positive and negative self-perception, contributing to overall self-worth (Rosenberg, 1965; Wang et al., 1999), including items like "I feel that I have a number of good qualities," rated on a 4-point Likert scale (1 = strongly agree, 4 = strongly disagree). The Subjective Vitality Scale measures participants' positive vitality and energy (Ryan and Frederick, 1997), with items such as "I feel alive and vital right now." The Chinese version of the Subjective Vitality Scale demonstrated high internal consistency (CR = 0.87) in sports settings (Liu and Chung, 2014), with responses rated on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree).

3.1.3 Data collection and analysis

Data were collected online via the popular Chinese professional survey platform Wenjuanxing.[2] Following the program center head's approval, athletes were sent the link to complete the scale. For analysis, Study 2 used SPSS 25.0 and AMOS 28.0. The exploratory factor analysis removed items with factor loadings below 0.5 or with significant cross-loadings. The confirmatory factor analysis evaluated construct validity. Excellent-fit indices included CFI ≥ 0.95, TLI ≥ 0.95, and RMSEA ≤ 0.06 (Hu and Bentler, 1999), with acceptable-fit indices of CFI ≥ 0.90, TLI ≥ 0.90, RMSEA ≤ 0.08 (Browne and Cudeck, 1992; Hu and Bentler, 1999), and PNFI ≥ 0.60 (Netemeyer et al., 1990). The appropriate range of χ^2/df was recommended to be between 2 and 5 (Schumacker and Lomax, 2004; Côté et al., 2017). Furthermore, correlation analysis was performed for reliability and validity tests.

3.2 Results

3.2.1 Exploratory factor analysis

The exploratory factor analysis on data comprising 11 items related to the autonomy-supportive and *laissez-faire* coaching styles used principal component analysis with two factors for extraction and employed varimax rotation. The sample suitability test (Kaiser-Meyer-Olkin = 0.92) and spherical test (χ^2 = 3923.27, p < 0.001) verified the sample's appropriateness for factor analysis. The autonomy-supportive subscale's factor loadings ranged from 0.76 to 0.88, while the *laissez-faire* subscale's loadings varied from 0.74 to 0.88, with no items displaying significant cross-factor loadings (Table 1). Each subscale had an eigenvalue greater than 1, cumulatively contributing 74.81% to the variance. The autonomy-supportive dimension's eigenvalue was 4.47, explaining 40.61% of the interpretable variance, and the *laissez-faire* dimension's eigenvalue was 3.76, accounting for 34.20%.

3.2.2 Confirmatory factor analysis

The confirmatory factor analysis was conducted with two dimensions (autonomy-supportive and *laissez-faire* coaching styles) serving as potential variables. The analysis yielded an acceptable fit to the data: χ^2/df = 4.14, RMSEA = 0.08, CFI = 0.97, TLI = 0.96, PNFI = 0.75.

To determine if the autonomy-supportive and *laissez-faire* coaching styles could be conceptualized as a single dimension, all items were used as observed variables, while a single latent variable was utilized to model the structural equations. The results demonstrated the following fit indices: χ^2/df = 27.67, RMSEA = 0.24, CFI = 0.70, TLI = 0.63, PNFI = 0.55. The model did not meet acceptable standards, indicating that the autonomy-supportive and *laissez-faire* coaching styles represent two distinct dimensions rather than a single dimension (Table 2).

3.2.3 Correlation analysis between the autonomy-supportive and *laissez-faire* coaching styles

A significant negative correlation was found between the two subscales (autonomy-supportive and *laissez-faire* coaching styles) (Table 3).

3.2.4 Reliability analysis

Reliability tests were conducted to assess the consistency of the autonomy-supportive and *laissez-faire* coaching styles (Table 4). The findings indicated that the internal consistency for both dimensions was excellent. Furthermore, the split-half reliability for both styles achieved high reliability indices.

3.2.5 Correlation analysis between the subscales and two additional scales

A correlation analysis was performed to evaluate the validity of the scale, incorporating two additional factors: self-esteem and subjective vitality (Table 5). The analysis revealed that self-esteem had a significant positive relationship with the autonomy-supportive coaching style and a substantial negative relationship with the *laissez-faire* coaching style. Likewise, subjective vitality showed a significant positive correlation with the autonomy-supportive coaching style and a notable negative relationship with the *laissez-faire* coaching style.

4 Discussion

The purpose of this study was to develop a scale to assess Chinese coaches' autonomy-supportive and *laissez-faire* coaching styles,

2 https://www.wjx.cn/

TABLE 1 Exploratory factor analysis: descriptive statistics and factor loadings.

Item	M	SD	Autonomy-supportive	*Laissez-faire*
Autonomy-supportive coaching style				
I feel that my coach provides me with choices and options	5.10	1.29	**0.76**	
I feel understood by my coach	4.72	1.49	**0.85**	
My coach conveyed confidence in my ability to do well in athletics	5.04	1.34	**0.84**	
My coach encouraged me to ask questions	5.13	1.34	**0.82**	
My coach listens to me regarding how I would like to do things	4.86	1.48	**0.88**	
My coach tries to understand my perspective before suggesting a new way of doing things	4.60	1.52	**0.86**	
Laissez-faire coaching style				
My coach remained inactive despite being aware of my consistently declining performance	2.72	1.38		**0.83**
My coach fails to provide feedback on whether my performance is satisfactory	2.69	1.42		**0.88**
Unless the situation is dire, my coach does not communicate with me	2.66	1.41		**0.84**
Once the training plan is established, my coach shows no interest in my training progress	2.51	1.34		**0.85**
Whenever I require assistance, my coach is invariably unavailable	2.72	1.38		**0.74**

Items of the autonomy-supportive coaching style were derived from the Sport Climate Questionnaire (https://selfdeterminationtheory.org/sport-climate-questionnaire/). Items of the laissez-faire coaching style were modified from laissez-faire leadership concepts (Bass and Avolio, 1996). The primary factor loadings are in bold. M, mean; SD, standard deviation.

TABLE 2 Two-dimension and single-dimension fitting indicators.

	χ^2/df	RMSEA	CFI	TLI	PNFI
Two-dimensional model	4.14	0.08	0.97	0.96	0.75
One-dimensional model	27.67	0.24	0.70	0.63	0.55

TABLE 3 Correlation analysis results between autonomy-supportive and *laissez-faire* coaching dimensions.

	Autonomy-supportive	*Laissez-faire*
Autonomy-supportive	1	
Laissez-faire	−0.50**	1

**$p < 0.01$.

TABLE 4 Reliability measures of the Chinese Coaches' Autonomy-Supportive—*Laissez-Faire* Coaching Style Scale.

	Internal consistency reliability	Split-half reliability
Autonomy-supportive	0.93	0.90
Laissez-faire	0.91	0.84

TABLE 5 Correlation analysis results between coaching styles and psychological factors: self-esteem and subjective vitality.

	Autonomy-supportive	*Laissez-faire*
Self-esteem	0.37**	−0.22**
Subjective vitality	0.58**	−0.22**

**$p < 0.01$.

providing a comprehensive foundation for evaluating coaching behavior. This scale included 11 items, with six items dedicated to measuring the autonomy-supportive coaching style and five items for assessing the *laissez-faire* coaching style. Evidence from this study supports the reliability and validity of the scale.

The autonomy-supportive subscale utilized the well-known Sport Climate Questionnaire, whereas the *laissez-faire* subscale, derived from the Multifactor Leadership Questionnaire, was adjusted to suit the sports context. After removing specific *laissez-faire* items, these two subscales formed a unique scale structure with contrasting directions. Unlike other instruments that assess coaching behavior, such as the Interpersonal Behaviors Questionnaire and the Coaches' Interpersonal Style Questionnaire, which measure dimensions like coaches' autonomy support and autonomy thwarting simultaneously

(Rocchi et al., 2017; Pulido et al., 2018), our scale recognizes these dimensions as inherently opposing and interconnected, underscoring the complexity of coaching styles. It acknowledges that a coach can adopt any coaching styles, as coaching styles are choices rather than personal characteristics. Knowledge of decision making between athlete and coach allows for the selection of different styles and encourages a "non-versus" approach to coaching, where different styles are not seen as better or worse, but as mean to achieve different outcomes (Mosston and Ashworth, 2008). This approach frames coaching as a structural act of teaching rather than one driven by personal preference (Pill et al., 2021c).

The notion of autonomy support is derived from self-determination theory within the realm of coaching styles, while *laissez-faire* originates from managerial leadership styles. To validate this scale, the study introduced two additional variables: self-esteem and subjective vitality. Aligning with previous research (Coatsworth and Conroy, 2009; Balaguer et al., 2012; Cheval et al., 2017), our findings indicate a positive association between the autonomy-supportive coaching style and both self-esteem and subjective vitality. Existing theories suggest that athletes' basic psychological needs may mediate the impact of coaching style on self-esteem (Coatsworth and Conroy, 2009; Cheval et al., 2017). Moreover, athletes' perceptions of autonomy-supportive coaching positively predict psychological need satisfaction, which, in turn, positively affects subjective vitality (Balaguer et al., 2012). Conversely, our study reveals a negative correlation between the *laissez-faire* coaching style and both self-esteem and subjective vitality, consistent with research indicating a negative association between *laissez-faire* coaching and positive psychological outcomes (Skogstad et al., 2007; Robert and Vandenberghe, 2022). Specifically, *laissez-faire* leadership has been linked to increased depressive symptoms and reduced positive mental health (Robert and Vandenberghe, 2022), possibly due to diminished autonomy and role clarity, leading to decreased well-being (Lundmark et al., 2022; Desgourdes et al., 2024). Our study also finds that the *laissez-faire* coaching style has a negative effect on positive psychological factors including self-esteem and subjective vitality. By bridging the gap between coaching and leadership styles, this study developed a scale that encompasses various coaching styles and offers valuable insights for future coaching practices.

The development of the Chinese Coaches' Autonomy-Supportive—*Laissez-Faire* Coaching Style Scale integrates coaching and leadership styles, supported by statistical evidence of its reliability and validity. Nevertheless, the study has limitations. First, it primarily surveyed athletes from provincial sports teams, which may limit the generalizability of the findings to different levels of sports teams. Future research should assess the scale's applicability to diverse athlete groups. Second, while this scale focuses on the "degree" of autonomy support from coaches, similar considerations may apply to other coaching styles, such as controlling styles. Third, although the scale incorporated insights from leadership research, further empirical studies are needed to elucidate its relationship with other psychological factors.

Data availability statement

The original contributions presented in the study are publicly available. The data can be found here: https://osf.io/5h6te/.

Ethics statement

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

Author contributions

WS: Methodology, Writing – original draft, Writing – review & editing. LW: Methodology, Writing – original draft. YD: Methodology, Writing – original draft. DZ: Conceptualization, Funding acquisition, Resources, 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.

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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Fernando Jorge Santos,
Instituto Politécnico de Setúbal (IPS), Portugal
Valerio Giustino,
University of Palermo, Italy

*CORRESPONDENCE
Liyan Wang
✉ wangly@sumhs.edu.cn

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Faster, more accurate, more confident? An exploratory experiment on soccer referees' yellow card decision-making

Hongbiao Wang[1], Chenping Zhang[1], Zhiguang Ji[1], Xiawen Li[1] and Liyan Wang[2]*

[1]Department of Physical Education, Shanghai University of Medicine and Health Sciences, Shanghai, China, [2]College of Rehabilitation Sciences, Shanghai University of Medicine and Health Sciences, Shanghai, China

This study aimed to examine how soccer referees make decisions about issuing yellow cards for fouls. The research involved 60 male participants, divided into expert (n=30) and novice (n=30) groups based on their experience and qualifications as referees. They took part in a 2×2×2 mixed-design experiment. The study looked at Decision-Making Style (DMS: Analytical Decision-Making [ADM] vs. Intuitive Decision-Making [IDM]), Video Type (yellow card foul vs. non-yellow card foul), and Referee Level (expert vs. novice) as independent variables. The dependent variables were accuracy rate (ACC), discrimination index (D), self-confidence index (C), and overconfidence index (OC). The findings showed that Analytical Decision-Making (ADM) led to higher accuracy compared to Intuitive Decision-Making (IDM). Expert referees demonstrated better accuracy than novice referees. There was also an interaction between Decision-Making Style and Referee Level, showing differences in the effectiveness of ADM and IDM between expert and novice referees. Additionally, the study revealed that both expert and novice referees showed overconfidence, with experts demonstrating significantly higher overconfidence, particularly during IDM. In conclusion, the research highlighted the complexity of referees' decision-making in high-pressure situations and emphasized the potential benefits of employing Analytical Decision-Making strategies. The study contributed to understanding cognitive biases in sports officiating and suggested the need for targeted training programs to help referees improve their performance and reduce overconfidence in challenging situations.

KEYWORDS

decision-making, soccer, referee, yellow card, overconfidence, analytical decision-making, intuitive decision-making

Introduction

Decision-making (DM) is critical to a football referee's responsibilities. On the field, when faced with complex foul situations, referees must make swift and accurate decisions. The swifter and more precise the DM, the smoother the flow of the game. Given the complexity of making good and quick DM, it comes as no surprise that referees demonstrate a relatively high rate of DM errors (Catteeuw et al., 2010). Numerous studies have highlighted the accuracy rate (ACC) of referee foul decisions, spanning from 50 to 93.1%

(MacMahon et al., 2007; Catteeuw et al., 2009; Mascarenhas et al., 2009; Schweizer et al., 2011; Mallo et al., 2012; Spitz et al., 2016, 2018; Jochim et al., 2018; Hossner et al., 2019). In football DM, the Union of European Football Associations (UEFA) Refereeing expert panel's ACC in actual matches is 70% (Fuller et al., 2004). Additionally, Gilis et al. (2007) conducted a retrospective video analysis of referee performance during the 2002 FIFA World Cup in Korea/Japan, revealing that referees made correct decisions in 60% of player-to-player contact fouls. This implies that in some studies, the ACC of football foul decisions is almost equivalent to flipping a coin (Samuel et al., 2021).

Given the considerable rate of erroneous DM behavior exhibited by referees, numerous studies have delved into the mechanisms and influencing factors underlying referees' DM. In terms of DM mechanisms, these include sequential effects (Plessner and Betsch, 2001), heuristic DM (Hepler and Feltz, 2012; Raab, 2012; Ramanayaka et al., 2023), stereotypes (Jones et al., 2002; Van Quaquebeke and Giessner, 2010), unwritten rules (Plessner and Raab, 1999; Raab et al., 2019a,b), and priming effects (Ste-Marie, 2003). As for the influencing factors of referees' DM, they primarily involve individual experience factors and match environment factors (Lane et al., 2006). Individual experience factors mainly include referees' physical fitness (Castagna et al., 2007; Castillo et al., 2019; Bouzas-Rico et al., 2022; Castillo-Rodríguez et al., 2023), visual skills (Pizzera and Raab, 2012), attention (Pietraszewski et al., 2014), stress coping (Wolfson and Neave, 2007), self-confidence (Çar et al., 2022), self-control (Samuel et al., 2018), expertise experience (MacMahon et al., 2007; Gilis et al., 2008; Catteeuw et al., 2009; Dawson, 2012), referee height (McCarrick et al., 2020), and self-efficacy (Guillén and Feltz, 2011). Regarding match environment factors, these include home advantage (Goumas, 2014; Lovell et al., 2014; Nevill et al., 2017; Picazo-Tadeo et al., 2017), the referee's position on the field (Mallo et al., 2012), player complaints after fouls (Lex et al., 2015), team uniform color (Krenn, 2014; Picazo-Tadeo et al., 2017), weather (Gaoua et al., 2017), height of the fouler (Van Quaquebeke and Giessner, 2010), team reputation (Jones et al., 2002), team ranking (Castillo et al., 2018), match time (Lago-Peñas and Gómez-López, 2016), and the distance of the audience from the pitch (Dohmen, 2008).

Despite the extensive research on the DM mechanisms and influencing factors of referees, which has generated significant findings (Bar-Eli et al., 2011) and enhanced our understanding of referees' DM (Raab et al., 2019a,b), there is a noticeable absence of studies on referees' decision-making style (DMS) within the context of DM mechanisms. Similarly, in the domain of personal influencing factors, there have been no reports on the issue of overconfidence in referees' DM.

Existing research has modeled the information processing of football referees' DM behavior (Plessner and Haar, 2006), suggesting that DM actions follow the cognitive process of stimulus-perception-categorization-memory-integration-behavioral response. Consequently, errors in referees' DM may stem from minor inaccuracies at different steps within the information processing sequence, and the probabilistic nature of Intuitive Decision Making (IDM) may serve as a significant source of error in penalty DM. The perspective on DMS posits that human judgment and DM are the result of the interaction between two distinct cognitive systems (System 1 and System 2) (Kahneman and Frederick, 2002). System 1 engages in intuitive, heuristic, automatic information processing, while System 2 engages in analytical, deliberate, and controlled information processing (Meyer and Frederick, 2023). For referees, the rapidity of DM may rely more on System 1's IDM, whereas the accuracy of DM may depend on the deliberate Analytical Decision Making (ADM) of System 2. However, it remains unclear how the two systems switch and operate in parallel. Some studies have indicated that when contextual cues (such as previous penalty DM) cast doubt on the initially triggered DM, they prompt deliberate and slower System 2 DM (Helsen et al., 2019). Therefore, given the characteristics of referee situation problem-solving, DM in refereeing sports contexts tends to be dominated by System 1 processing patterns, supplemented by System 2 processing patterns, adhering to a dual-system processing paradigm. Consequently, IDM becomes the primary form of DM in refereeing sports contexts, with rapidity, probability, and directness becoming the fundamental characteristics of referees' sports IDM (Araújo et al., 2019).

Overconfidence is when an individual is overly optimistic about their knowledge, abilities, or judgments (Alpert and Raiffa, 1982). Self-aggrandizing individuals tend to overestimate their accuracy and control, underestimate risk and uncertainty, and ignore or insufficiently consider information that contradicts their views (Hoffrage, 2022). While overconfidence can foster ambition, determination, perseverance, morale, and the credibility of bluffs, it can also lead to flawed assessments, unrealistic expectations, and risky decision-making. Overconfidence may result in overestimation of one's abilities or underestimation of opponents, task difficulty, or potential risks and can create illusions of control over events and immunity to risk (Block and Colvin, 1994).

In sports decision-making, overconfidence is often seen as egotism and a pervasive cognitive bias (Fogarty and Else, 2005). In soccer, referees are required to make quick and accurate decisions based on their understanding of the game rules, their observation of the situation on the field, and their own experience and intuition. However, overconfidence in their decision-making can lead to situations getting out of control. Referees must balance fairness and accuracy in making decisions regarding penalties while ensuring the smooth flow of the game. Overconfidence in their decision-making can exacerbate conflicts and lead to serious consequences (Erceg and Galić, 2014).

The systematic cognitive biases in DM described above, whether related to DMS or overconfidence, represent only a fraction of human cognitive fallacies. Behavioral experiments have shown that human thought processes exhibit systematic limitations and that judgment and DM are often only marginally rational (Hastie and Dawes, 2010). Various cognitive deficits, heuristic DM biases, and habitual thinking patterns influence most sports judgment and DM (Bennis and Pachur, 2006; Hepler and Feltz, 2012; Raab, 2012; Raab, 2017; Raab et al., 2019a,b; Ramanayaka et al., 2023). Similar systematic DM biases probably exist in soccer referee penalty DM, warranting an experimental exploration of the behavioral cognitive mechanisms underlying referee penalty DM. Hence, this study aimed to conduct a systematic experimental exploration of referee penalty DMS and overconfidence, which will not only help to correctly understand the referee's task and the behavioral cognitive mechanisms involved in penalty DM but also enable the referee to improve the probability of rational DM in penalty DM behavior.

By comparing expert and novice referees, the study contributes to the understanding of how experience level affects decision-making processes and overconfidence, which can inform training programs for referees at different stages of their careers. The findings related to cognitive biases, such as overconfidence, in the context of sports officiating add to the broader literature on cognitive biases in high-stakes, time-pressured decision-making environments. The study contributes to the knowledge of how individual experience factors and match environment factors influence referees' decision-making, building on previous research by providing a more comprehensive view of these influences. The research explores the interplay between System 1 (intuitive) and System 2 (analytical) in the context of sports officiating, contributing to the understanding of how these systems operate in high-pressure, real-time decision-making scenarios. Overall, this study enriches the body of knowledge surrounding sports officiating by providing empirical evidence on decision-making styles, the role of overconfidence, and the impact of expertise level, while also offering practical implications for training and performance enhancement.

So, the Purpose of this study: (I) Using soccer yellow-card foul videos as experimental materials, we explored the performance differences of soccer referees under different DMS when making decisions on whether to issue a yellow card or not. (II) We seek to assess the prevalence of overconfidence among referees of varying expertise levels by comparing penalty ACC, discrimination index (D), and self-confidence index (C). Additionally, we aimed to explore the effects of different penalty video types (VTs), DMS, and refereeing levels on overconfidence. Overconfidence holds significant implications for referees' successive judgments and DM processes. This study explored the effect of overconfidence on different penalty VTs, DMS, and refereeing levels, as it served as a crucial reference point for referees' ongoing DM endeavors. Hypothesis of this study: (I) Call performance might vary across different DMS for referees of varying expertise levels, and it might be influenced by both yellow and non-yellow card call VTs. Novice referees might exhibit better call performance in analytical decision-making (ADM) tasks compared to intuitive decision-making (IDM) tasks. Conversely, expert referees' self-confidence in IDM may surpass that in ADM. Novice referees could potentially outperform IDM referees in terms of ADM discrimination, and the impact of different DMS on novice referees' discriminative ability may exceed that of IDM referees. Moreover, different DMS may have a greater impact on novice referees compared to IDM referees. (II) There is evidence of overconfidence in referees' decisions regarding soccer foul calls, and there might be an interaction between refereeing level and DMS. Expert referees might be more susceptible to overconfidence in IDM.

Materials and methods

Participants

Sixty male participants volunteered for this experiment and were divided into the expert group ($n = 30$) and the novice group ($n = 30$) based on their level of refereeing experience. In China, soccer referee grades are categorized into 5 levels from low to high, i.e., Level 3, Level 2, Level 1, National Level, and International Level. Each level has corresponding theoretical and practical examination standards. Generally speaking, undergraduates of soccer majors can get the qualification of level 3 referee, and graduates of master's degree of soccer majors can get the qualification of level 2 referee. Enforcement of professional soccer matches [e.g., the Chinese Football Association (CFA) Division Two League] requires referees to be qualified as Level 1 referees or above.

The expert group comprised referees at national level 1 and above, including 9 national level referees and 21 national level 1 referees, affiliated with the Liaoning Provincial Football Association, Shenyang Football Association, and Changchun Football Association. In this study, we defined "expert" as a referee with level one referee standard or above and a referee with at least 5 years of experience in enforcing professional league matches. Those who met this criterion were included in the expert subject group. "Novices" were defined as graduate students or undergraduates who had level 3 referee standards or had experience in amateur soccer refereeing. Expert group participants were recruited through the coordination of the Chinese Football Association, recommended by the Liaoning Provincial Football Association, Shenyang Football Association, and Changchun Football Association, and the research group recruited by phone to confirm the participation of some active referees and non-active referees in the experiment. Two of them were active referees in the Chinese Football Association Super League, eight were active referees in the Chinese Football Association China League, and 20 had experience officiating in professional leagues such as the Chinese Football Association China League or the Chinese Football Association Division Two League, all with enforcement experience of more than 6 years. The subjects in the novice group were recruited from graduate and undergraduate students majoring in soccer at Shenyang Sports University, with some refereeing experience and a referee rating of national level 3 or below.

All participants completed a self-report questionnaire before the experiment that included demographic variables, health status, history of illness, history of brain injury, vision and correction, dominant hand, and experience of whether they had participated in a similar experiment. All participants reported good health, no history of genetic disease, no brain injury, no neurological disease, normal or corrected vision, and no prior relevant experimental experience. All participants were right-handed and provided informed consent before the experiment. They received modest compensation upon completion of the experiment.

As shown in Table 1, the average experience of participants in the expert group of this study in enforcing professional matches was 9.17 years ($M = 9.17$; $SD = 2.25$), while the average experience of participants in the novice group in enforcing amateur matches was 1.6 years ($M = 1.6$; $SD = 0.72$), and the average experience of participants in the expert group of the refereeing experience in del Campo et al. (2018) study was 10.25 years ($M = 10.25$; $SD = 2.03$), but in their study did not specify whether they were refereeing professional or amateur matches. In contrast, in Spitz et al. (2018) study, the average refereeing experience of the sub-elite referees was 12 years. Considering that the participants in the expert group in this study were experienced in enforcing professional matches, to become a referee enforcing professional matches, one has to accumulate many years in enforcing amateur matches (e.g., U-series youth soccer

TABLE 1 Basic information of experimental participants.

	Age ($M \pm SD$)	Referee level (n)		Enforcement experience ($M \pm SD$)
Expert	34.77 ± 6.67	National level (9)	National level 1 (21)	9.17 ± 2.25
Novice	22.43 ± 5.06	National level 3 (12)	No level (18)	1.6 ± 0.72

matches), therefore, referring to previous studies, the definition of the expert criterion in this study is still appropriate.

Instruments

For experimental video editing and the DM task system preparation, a desktop computer with the following specifications was utilized: a 22-inch color display, operating on a 64-bit system, equipped with a 2.3GHz processor. The screen resolution was set at 1024 × 768 pixels with a refresh rate of 60 Hz, and the viewing distance was maintained at 75 cm.

E-prime 3.0psychological experiment programming software was used for intuitive psychological experiment programming. It offered ease of operation through drag-and-drop video functionality, allowing for high customizability of stimulus video presentation and behavioral data collection. It also ensured millisecond-level temporal accuracy and was used for DM tasks and data collection.

Additionally, Adobe Premiere Pro 2020, a professional video editing software, was adopted for editing experimental videos. It facilitated adjustments in video duration, sound management, mirroring, and other necessary modifications.

Materials

The editing process involved the following steps: (1) Interception of video clips. The slow-motion replays of suspected yellow card fouls (with a controlled ratio of 1:2 for yellow card to non-yellow card incidents) were intercepted from footage of the 2018 Fédération International de Football Association (FIFA) World Cup Russia matches, and the video was intercepted to obtain a total of 150 video clips. (2) Video framing point and video duration editing. The frame points of the video screen were determined, covering the duration from the beginning to the end of the player's foul in the video. The video duration was adjusted to fall within the range of 1,000–2000 ms. (3) Video muffling processing. To minimize interference from sound in the videos for participants, the edited videos were muffled. (4) Final video compilation: a total of 150 videos were obtained to meet the specified requirements, including 50 videos of yellow card penalties and 100 videos of non-yellow card penalties.

The screening process involved the following steps: (1) preliminary screening. Shenyang Sports University 2 soccer national referee group assessed suspected yellow card fouls in slow motion according to yellow card rules. The score was divided into 4 probability levels: 100–75%, 75–50%, 50–25%, and 25–0%. Slow-motion replay videos scoring within the 75–50% range for showing a yellow card were retained as yellow card penalty stimulation videos, while those scoring within the 50–25% range were retained as non-yellow card penalty stimulation videos. After preliminary screening of the 150 edited videos, only those agreed upon by at least two referees proceeded. Ultimately, 106 videos passed preliminary screening, including 38 yellow card penalty videos and 78 non-yellow card penalty videos. (2) DM task system preparation: Using E-prime 3.0 psychological experimental programming software, the 106 videos were programmed into the DM task system. The system actively collected data on participants' reaction time and correctness rate of DM.

The second screening process was as follows: 106 DM tasks were performed by 30 soccer-specialized college students from Shenyang Sports University. Videos with response times falling within 2,000 ms and correctness rates ranging between 60 and 90% passed the final screening. Consequently, a total of 100 videos met these criteria and were retained for further analysis.

Screening results were as follows: The final number of videos obtained was 100, with 10 designated for the practice phase and 90 for the formal experimental phase. Among these, 30 were yellow card penalty videos and 60 were non-yellow card penalty videos. For ADM stimulus videos, participants were required to respond to penalties within 2,000 ms of the end of video playback. The duration of video playback ranged from 1,000–2,000 ms, allowing participants a total response time of 4,000 ms. The ADM videos consisted of 30 non-yellow card penalty videos and 15 yellow card penalty videos. Similarly, for IDM stimulus videos, participants had to respond within 500 ms of the end of video playback. Slow-played videos were processed with a 2-fold fast playback. The video playback duration ranged from 500 to 1,000 ms, providing a response window of 1,500 ms. The IDM video consisted of 30 non-yellow card penalty videos and 15 yellow card penalty videos.

Design

The experiment used a 2 × 2 × 2 three-factor mixed experimental design. Among the three independent variables, the between-subjects variable was Referee Level (RL: expert, novice), while the within-subjects variable 1 was DMS (ADM, IDM), and the within-subjects variable 2 was VT (yellow card foul, non-yellow card foul).

The dependent variables included decision-making accuracy (ACC), discrimination index (D), confidence (C), and overconfidence index (OC). Decision-making accuracy (ACC) represented the percentage of correct responses out of the total responses by experimental participants, including both correct responses to go and no-go stimuli. It reflected the proficiency level in judgmental DM tasks. Discrimination index (D) measured the experimental participant's perception of the video stimuli, indicating their ability to correctly recognize target or non-target stimuli. Confidence (C) reflected the participants' confidence in their judgment during DM tasks, ranging from 1 (not confident at all) to 10 (very confident). For the OC, following Koriat et al. (1980), if a participant exhibited high confidence levels (rated 8, 9, or 10 out of 10) for a question but answered incorrectly, it indicated overconfidence. The participant's overconfidence scores for all questions were summed and averaged by dividing the total by the number of questions. A higher value indicated a greater degree of overconfidence.

Discrimination index (D) was calculated as follows: (1) When a participant was presented with a signal (treating the yellow stimulus video as a signal), it was categorized as a hit if the participant identified it as a signal, and a miss if mistaken as noise (treating the non-yellow stimulus video as noise). (2) When a participant was presented with a noise, it was categorized as a false alarm if the subject identified it as a signal, and it was correctly rejected if identified as a noise, as shown in Table 2.

To calculate the D, we first determine the probabilities of hitting and false alarms. Given hitting probability (PH) = 12/15 = 0.8 and false alarm probability (PF) = 3/30 = 0.1. Referring to the Probability of Z (POZ) conversion table, PH = 0.8 corresponded to a *Z*-score of 0.84, and PF = 0.1 corresponded to a *Z*-score of −1.28. Therefore, D = *Z*-score (hitting) – *Z*-score (false alarm) = 0.84 – (−1.28) = 2.12.

Procedure

Before the experiment started, participants completed an informed consent form. The staff provided an overview of the experimental procedures and precautions and recorded participants' basic information including name, contact details, years of officiating experience, and refereeing grade.

The experimental practice phase consisted of 10 trials, including 5 ADM videos (2 yellow cards and 3 non-yellow cards) and 5 IDM videos (2 yellow cards and 3 non-yellow cards). Following the practice phase, participants took a 5-min break to rest. During this break, they were informed of the experiment's precautions and ensured comprehension before proceeding to the formal experiment. The experimental procedure is shown in Figure 1.

During the formal experiment phase, participants were briefed on the experimental procedure. The entire set of experimental videos was presented 90 times. These videos depicted slow-motion replays of fouls in soccer matches, each lasting between 500 and 2000 ms. Participants were tasked with determining whether each foul constituted a yellow-card offense and responding accordingly with designated keystrokes ("F" for yellow-card fouls and "J" for non-yellow-card fouls). In ADM, participants were given up to 2,000 ms to deliberate on each decision, followed by the determination of C within a 2,000 ms window after each decision. C used a 10-point Likert scale ranging from "not at all confident" to "very confident." Conversely, in IDM, participants were required to make an immediate decision upon viewing the foul video, with the C determined after 2,000 ms. Responses in ADM were considered valid within 2,000 ms post-video playback, with any responses beyond this window marked as misses. Similarly, IDM responses were valid within 500 ms post-video playback. Trials appeared randomly with intervals ranging from 1,000 to 2,000 ms. The whole task duration was approximately 8 min, with 45 trials each for ADM and IDM, and alternation between expert and novice participants to mitigate sequential effects.

TABLE 2 Calculation of the discrimination index D.

	Reporting (yellow card)	Reporting (non-yellow card)
Yellow card	12	3
Non-yellow card	3	27

Statistical analyses

SPSS Statistics 22.0 was used for data analysis, with DMS, VT, and RL serving as independent variables. Repeated measures analysis of variance (ANOVA) was conducted for ACC, D, C, and OC. The normality and homogeneity of variance for the aforementioned variables were assessed using the Shapiro–Wilk test and Levene's test, respectively. Parametric tests were applied as the data met the assumptions of normality and homogeneity of variance ($p > 0.05$). A 2 × 2 × 2 repeated measures ANOVA was performed with group (expert, novice) as a between-subjects factor, and DMS (ADM, IDM) and VT (yellow card penalty, non-yellow card penalty) as within-subjects factors to investigate the effect of the independent variables on the dependent variable. Effect sizes in the repeated measures ANOVA were calculated as η^2 and a *p*-value of less than 0.05 was considered a significant difference.

Results

A repeated measures ANOVA was conducted with DMS (ADM, IDM), VT (yellow card video, non-yellow card video), and RL (expert, novice) as factors, and the percentage of correct responses (ACC) as the dependent variable. The sphericity assumption was satisfied ($p > 0.05$). The results indicated a significant main effect of DMS, $F(1,58) = 5.291$, $p = 0.025$, $\eta^2 = 0.084$, indicating that ADM correctness ($M = 0.763$, $SD = 0.006$) was significantly higher than IDM correctness ($M = 0.747$, $SD = 0.006$), supporting Hypothesis 1. The main effect of VT was not significant, $F(1,58) = 0.291$, $p = 0.592$, $\eta^2 = 0.005$. However, a significant main effect of RL was observed, $F(1,58) = 326.405$, $p < 0.001$, $\eta^2 = 0.849$, with expert referees demonstrating a higher accuracy in foul calls ($M = 0.843$, $SD = 0.007$) compared to novice referees ($M = 0.666$, $SD = 0.007$), as detailed in Table 3, which also supports Hypothesis 1.

The interaction between DMS and RL was significant, $F(1,58) = 20.093$, $p = 0.001$, $\eta^2 = 0.000$. Further simple effects analyses were conducted to explore this interaction. Among expert-level participants, there was no significant difference in the percentage of correct responses between ADM and IDM videos (ADM: $M = 0.835$, $SD = 0.008$; IDM: $M = 0.851$, $SD = 0.009$; $p > 0.05$). In contrast, novice-level participants showed a significant difference in the percentage of correct penalties depending on DMS ($p < 0.05$); specifically, the percentage of correct analytical penalties ($M = 0.690$, $SD = 0.008$) was significantly higher than that of intuitive penalties ($M = 0.643$, $SD = 0.009$), confirming Hypothesis 1 and indicating that different DMS only affect novice penalties. This finding is supported by the data presented in Table 3.

A 2 (DMS: ADM, IDM) × 2 (RL: expert, novice) repeated measures ANOVA was conducted with DMS as the within-subjects independent variable and RL as the between-subjects independent variable, using the C as the dependent variable. The test of sphericity was established with $p > 0.05$. The results showed a non-significant main effect of DMS [$F(1,58) = 0.668$, $p = 0.417$, $\eta^2 = 0.011$], which did not support Hypothesis 1. However, the main effect of RL was significant [$F(1,58) = 79.018$, $p = 0.000$, $\eta^2 = 0.577$], revealing that C of expert-level referees was significantly higher (8.629 ± 0.115) for foul calls compared to novice-level referees (7.180 ± 0.115), thereby supporting Hypothesis 1. The interaction between DMS and RL was

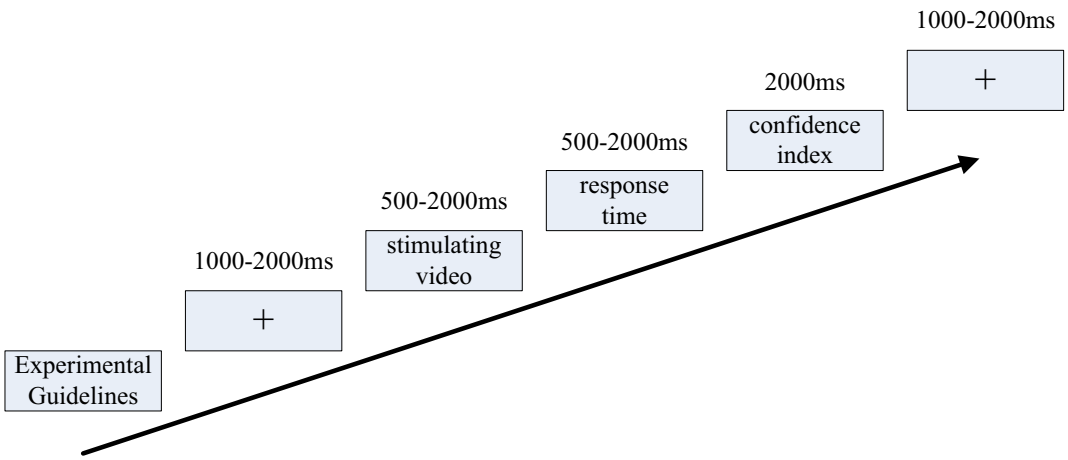

FIGURE 1
Experiment flowchart.

significant [$F(1,58) = 31.874$, $p = 0.000$, $\eta^2 = 0.577$]. Subsequent simple effects analyses of this interaction, with RL tested separately at each of the two levels of DMS, revealed significant differences in self-confidence indices between expert-level participants when confronted with ADM versus IDM videos, $p < 0.05$. Specifically, experts showed a lower C for ADM (8.343 ± 0.141) compared to IDM (8.914 ± 0.120). Similarly, significant differences in self-confidence indices were found among novice-level participants when faced with different types of DM judgments ($p < 0.05$). Notably, self-confidence indices for ADM judgments (7.393 ± 0.141) were significantly higher than for IDM judgments (6.967 ± 0.120), confirming experimental Hypothesis 1. However, these findings suggest that different DMS have different effects on expert and novice participants, as shown in Table 4.

A 2 (DMS: ADM, IDM) × 2 (RL: expert, novice) repeated measures ANOVA was conducted with DM penalty type as the within-subjects independent variable and RL as the between-subjects independent variable, using the D as the dependent variable. A test of sphericity was established with $p > 0.05$. The results revealed a significant main effect of DMS [$F(1,58) = 26.079$, $p = 0.000$, $\eta^2 = 0.310$]. Specifically, a significantly higher D for participants penalized for ADM (2.103 ± 0.056) than those penalized for IDM (1.829 ± 0.048), thereby supporting hypothesis 1. Additionally, a significant main effect of RL was observed [$F(1,58) = 78.296$, $p = 0.000$, $\eta^2 = 0.574$], with a significantly higher D for foul calls by referee's expert (2.362 ± 0.063) compared to novices (1.570 ± 0.063). Furthermore, the interaction between DMS and RL was significant [$F(1,58) = 15.487$, $p = 0.000$, $\eta^2 = 0.211$]. Subsequent simple effects analyses of this interaction, with RL tested separately at each of the two levels of DMS, revealed that the difference in D (ADM: 2.394 ± 0.079; IDM: 2.331 ± 0.069) between expert-level participants when faced with ADM versus IDM was not significant ($p > 0.05$). However, novice-level participants showed significant differences in penalty D when faced with different DMS, $p < 0.05$. Specifically, D for ADM penalties (1.813 ± 0.079) was significantly higher than for IDM penalties (1.326 ± 0.069), confirming experimental hypothesis 1. These findings suggest that different DMS had an effect on the recognition of yellow card penalties only for novices, as shown in Table 5.

TABLE 3 Decision-making style (DMS), VT, and RL on response correctness (ACC) for repeated measures ANOVA.

Source of variance	*df*	*F*	*p*	Partial η^2
DMS	1	5.291	0.025	0.084
VT	1	0.291	0.592	0.005
RL	1	326.405	0.000	0.849
DMS × VT	1	0.425	0.517	0.007
DMS × RL	1	20.093	0.000	0.257
VT × RL	1	2.816	0.099	0.046
DMS × VT × RL	1	1.007	0.320	0.017

TABLE 4 Repeated-measures ANOVA of self-confidence index (C) in DMS penalties for different RL.

Source of variance	*df*	*F*	*p*	Partial η^2
DMS	1	0.668	0.417	0.011
RL	1	79.018	0.000	0.577
DMS × RL	1	31.874	0.000	0.355

A repeated measures ANOVA with a 2 (DMS: ADM, IDM) × 2 (VT: yellow card video, non-yellow card video) × 2 (RL: expert, novice) design was conducted, with DMS and VT as within-subjects independent variables and RL as the between-subjects independent variable, using OC as the dependent variable. The sphericity assumption was confirmed ($p > 0.05$). The results showed a significant main effect of DMS [$F(1,58) = 6.253$, $p = 0.015$, $\eta^2 = 0.097$]. *Post hoc* comparisons indicated that the OC was significantly lower for ADM (23.883 ± 0.568) than for IDM (25.650 ± 0.410), supporting Hypothesis 1. Additionally, a significant main effect of VT was observed [$F(1,58) = 11.551$, $p = 0.001$, $\eta^2 = 0.166$]. There was also a significant main effect of RL [$F(1,58) = 95.421$, $p = 0.000$, $\eta^2 = 0.622$]. Expert-level referees exhibited a significantly lower OC in foul calls (23.883 ± 0.568) compared to novice-level referees (25.650 ± 0.410), as shown in Table 6, thus supporting Hypothesis 2.

TABLE 5 Repeated-measures ANOVA of discrimination index (D) for different RL in different DMS.

Source of variance	*df*	*F*	*p*	Partial η^2
DMS	1	26.079	0.000	0.310
RL	1	78.296	0.000	0.574
DMS × RL	1	15.487	0.000	0.211

TABLE 6 Repeated-measures ANOVA of DMS, VT, and RL on overconfidence index (OC).

Source of variance	*df*	*F*	*p*	Partial η^2
DMS	1	6.253	0.015	0.097
VT	1	11.551	0.001	0.166
RL	1	95.421	0.000	0.622
DMS × VT	1	10.115	0.002	0.148
DMS × RL	1	6.136	0.016	0.096
VT × RL	1	65.038	0.000	0.529
DMS × VT × RL	1	2.216	0.142	0.037

The interaction between DMS and VT was found to be significant, $F(1,58) = 10.115$, $p = 0.002$, $\eta^2 = 0.148$. Further analyses were conducted to explore the interaction between DMS and VT, with DMS tested at two levels of VT. Subsequent tests for VT revealed a significant difference in OCs between videos depicting yellow card penalties and those depicting non-yellow card penalties, $p < 0.05$. Specifically, the overconfidence indices for non-yellow card penalty videos ($M = 24.767$, $SD = 0.550$) were significantly higher than those for yellow card penalty videos ($M = 23.000$, $SD = 0.640$). However, the difference in overconfidence indices for IDM in both yellow and non-yellow card penalties (yellow penalty video: 25.550 ± 0.461; non-yellow penalty video: 25.750 ± 0.448) was not significant ($p > 0.05$). This finding supports Experimental Hypothesis 2, suggesting that only ADM affected yellow and non-yellow card penalties.

The interaction between DMS and RL was found to be significant (Table 6), $F(1,58) = 6.163$, $p = 0.016$, $\eta^2 = 0.096$. Further analyses were conducted on the interaction between DMS and RL, with RL tested at each level of DMS separately. It was found that the difference in overconfidence indices (ADM: 21.367 ± 0.804; IDM: 21.383 ± 0.579) between novice-level experimental participants exposed to ADM and IDM videos was not significant ($p > 0.05$). In contrast, a significant difference in OCs was observed among expert-level experimental participants when confronted with different DMS ($p < 0.05$). Specifically, OC for ADM (26.400 ± 0.804) was significantly lower than that for IDM (29.917 ± 0.579), indicating that different DMS only influence the overconfidence of expert sentencing, thus supporting Hypothesis 2 (Figure 2).

The interaction between VT and RL was found to be significant [$F(1,58) = 65.038$, $p = 0.000$, $\eta^2 = 0.529$]. Further simple effects analyses were conducted on the interaction between VT and RL, with RL tested at each level of VT separately. Among expert-level experimental participants, there was a significant difference in overconfidence indices between yellow-card penalties and non-yellow-card penalties in videos ($p = 0.002$). Specifically, the OC for yellow-card calls (yellow-card call videos: 28.833 ± 0.568) was significantly higher than that for non-yellow-card calls (27.483 ± 0.493). Similarly, among novice-level experimental participants, there was a significant difference in OCs between yellow-card calls and non-yellow-card calls in videos ($p = 0.000$). OC for yellow-card calls (yellow-card call videos: 28.833 ± 0.568) was significantly greater than that for non-yellow-card calls (27.483 ± 0.493). Moreover, OC for yellow card penalty videos (19.717 ± 0.568) was significantly lower than that for non-yellow card penalties (23.033 ± 0.493). These findings suggest that OCs were affected by both yellow and non-yellow video DM penalties for both experts and novices.

Discussion

Kahneman and Egan (2011), winner of the 2002 Nobel Prize in Economics, categorized the human DM thought process into IDM in System 1 and ADM in System 2. Both DM systems have controversial effects on DM performance. System 1's IDM, characterized as "thermo-cognitive," encompasses fast, parallelizable, automated, unconscious processes that require minimal cognitive resources, are associative, emotional, and effortless, and yield result-oriented, holistic, preconceived outcomes (Betsch and Kunz, 2008; Alós-Ferrer and Strack, 2014; Achtziger et al., 2015). In contrast, System 2's ADM, termed "cold cognition," involves controlled" or "thoughtful" processes that consume cognitive resources, are consciously monitored, and unfold slowly based on logical rules, cause-and-effect relationships, and a hierarchical, sequential, process-oriented approach (Shiloh et al., 2002; Shahar et al., 2015). While System 2's ADM is presumed to exhibit fewer mistakes and greater accuracy than System 1's IDM in general DM contexts, evidence from numerous studies suggests that humans can rely on intuition to swiftly and accurately navigate motor-related DM tasks across various contextual cues (Raab and Johnson, 2008; Schweizer et al., 2011; Hepler and Feltz, 2012; Collins et al., 2016; Raab et al., 2019a,b; Samuel et al., 2019). However, the fast contingency of IDM determines the probabilistic nature of DM performance, with speed prioritized over accuracy under conditions of time constraints and spatial compression. Drawing upon Klein et al.'s (2010) Recognition Primed-Decision (RPD) model DM in the domain of motion can be conceived as a three-stage recognition process: (I) simple match (recognizing a situation and associating it with the first adequate option), (II) diagnosing the situation (encountering an unfamiliar situation and requiring time to adapt a typical action), and (III) evaluating a course of action (assessing the relevance of the first option through mental visualization). Macquet's (2020) literature review of RPD modeling in sports suggests that 60–81% of sports-related DM involves simple matching, 13–28% is associated with diagnostic situations, and 3–24% pertains to assessing a course of action. In addition, compared to athletes, rugby coaches experience less time pressure during DM and thus often engage in thoughtful or ADM (Collins et al., 2016). However, in soccer refereeing penalty DM, it remains to be empirically validated whether all penalty DM behaviors are IDM. Although fast and accurate decisions are conducive to the control and flow of the game, soccer refereeing DM does not invariably involve time-urgent, high-pressure DM; more often than not, accuracy processing is prioritized over speed processing. Furthermore, the demarcation between IDM and ADM is not always clear-cut, suggesting that DM in sports settings may

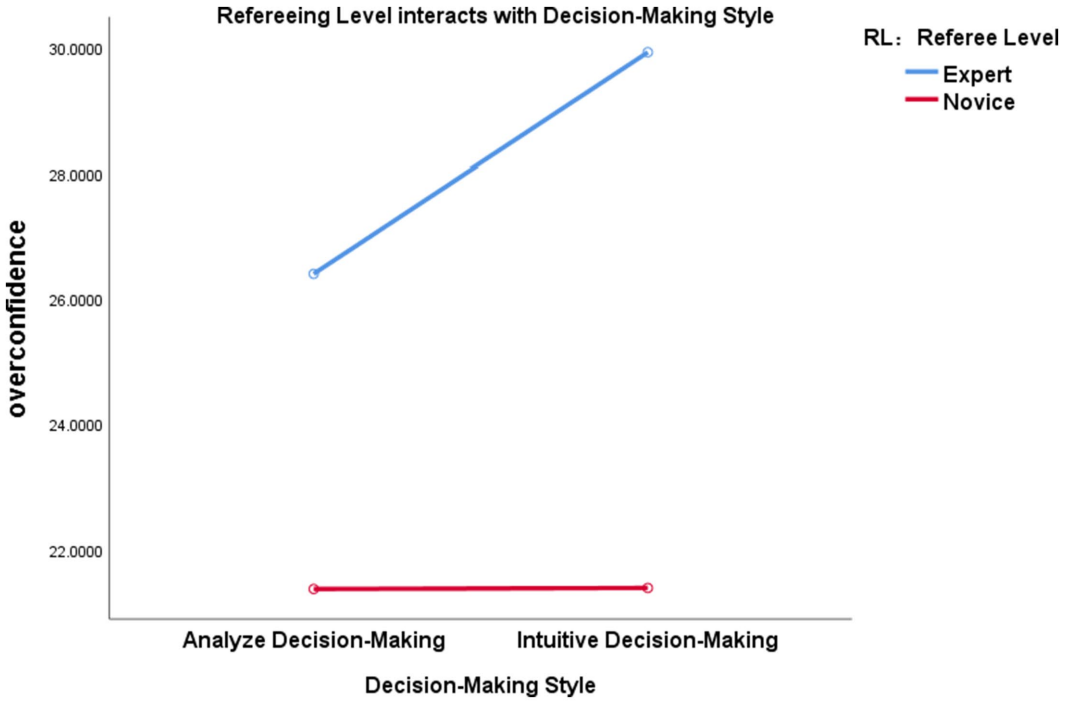

FIGURE 2
Referee level (RL) interacts with DMS.

occur along a continuum between IDM and ADM processes (Kahneman and Klein, 2009). Indeed, many sports DM processes may commence with intuition, which is subsequently validated and refined through analysis. From athlete DM (Ashford et al., 2021a,b; Hallé Petiot et al., 2021) to coach DM (Collins et al., 2016; Richards et al., 2016; Almeida et al., 2019) and referee DM (Kittel et al., 2021, 2023; Samuel et al., 2021), the Naturalistic Decision Making (NDM) approach suggests (Bossard et al., 2022) that athletes' on-field decisions lean toward IDM, referees' on-field decisions have equal importance of IDM and ADM, while coaches' on-field decisions are dominated by ADM.

Despite previous research assuming that referees mostly rely on intuition to process information in contact situations (Plessner et al., 2009), the current study revealed that experimental participants were significantly more accurate in ADM compared to IDM in terms of penalty performance. This finding implies that ADM may play a crucial role in determining whether or not to issue a yellow card in DM situations. Regarding the value of C, no significant difference was observed between different DM systems. However, at different levels of expertise, participants' performance in both DM systems remained consistent among expert-level participants, whereas novice-level participants showed a preference for ADM over IDM. It appears that experts can engage in both IDM and ADM concurrently, whereas novices rely more heavily on ADM in System 2. Analytical thinking can improve novice penalty performance under sufficient time. When faced with the binary task of classifying yellow card penalties, soccer referees must decide whether to issue a yellow card or administer a verbal warning in response to a foul situation, a task involving perceptual classification. Referees must consider visible cues to determine which criteria correspond to the card or no-card category. The accuracy of penalty DM depends on the referee's ability to match cues with yellow card context encoding in long-term memory, with the current scenario processed through rapid retrieval and comparison with past yellow card episodes. Time constraints may prompt referees to respond via IDM rather than deliberate ADM processes. However, Schweizer et al. (2011) also argued that many DM tasks in soccer refereeing, such as discreet red and yellow card DM or offside DM, may necessitate more deliberate ADM over IDM.

Although Dijksterhuis et al. (2006) asserted in "Science" that IDM systems outperformed ADM systems, this assertion was not corroborated by the present study. Similarly, D, another performance metric, indicated that ADM outperformed IDM situations and was influenced by the level of refereeing. A simple effects analysis found that expert DM accuracy was not influenced by DMS, whereas novices were influenced by the decision-making system. This contradicted Hogarth and Schoemaker's (2005) study, which suggested that subjects with rapid, intuitive characteristics in the DM process were generally more accurate compared to those with meticulous, analytical tendencies. In this study, ADM proved superior to IDM across all three dependent variables, and IDM did not demonstrate superior accuracy, speed, or performance characteristics in the soccer yellow card penalty DM task. It is obvious that in the formal yellow card penalty DM situation, there is no time pressure within the sub-500 milliseconds range, as seen in baseball batting (Chen et al., 2021). The process may take seconds or even tens of seconds from the foul occurrence to the card issuance, suggesting that the yellow card penalty DM paradigm may begin in IDM and be refined in ADM. In other words, both System 1 and System 2 could be involved in the DM process. Dual-system processing theory offers insights into information processing in yellow-card-foul DM situations, suggesting that the initial phase of penalty DM tends to favor contingent intuitive processing, wherein multiple features (e.g.,

cues) of the DM situation can be processed simultaneously in a very short period. Intuition is believed to rely on an extensive knowledge base in long-term memory acquired through associative learning (Betsch, 2008; Hogarth, 2008) and operates as a network of associations. IDM information processing resembles distributed parallel processing, while ADM processing more closely resembles serial processing. The serial computation of information processing in the yellow-card penalty DM context differs from distributed parallel computation, with advantages such as high accuracy, predictable results, and increased controllability in DM. It is clear that yellow-card penalty DM does not share the unique characteristics of typical sports DM. Yellow card penalty DM does not pursue speed priority as much as the most unique characteristics of time urgency and environmental coordination in ordinary sports DM. Instead, speed priority will be replaced by accuracy priority in yellow card penalty DM scenarios where the sports environment does not present urgent situations.

Many studies have shown that overconfidence in judgment and DM is widespread and frequent. It has been identified in everyday life activities. Overconfidence in DM has been frequently observed in the professional practices of numerous disciplines, such as doctors, lawyers, engineers, psychologists, and stock investors (Belsky and Gilovich, 2009). Surprisingly, research on overconfidence in the context of sports refereeing remains scarce. The overconfidence bias manifests when individuals' confidence in their judgments exceeds the accuracy of those judgments. This traditional measure of overconfidence was used in the current study, revealing that both expert and novice referees, engaged in the yellow-card DM paradigm task, were influenced by their level of refereeing expertise, DMS, and the binary variable of whether a penalty was awarded or not.

In terms of referees' yellow-card penalty DM self-confidence, expert referees were significantly more self-confident in awarding penalties than novice referees, consistent with previous research on team sport referees, where high-level referees had significantly greater self-confidence than low-level referees (Çar et al., 2022). In addition, refereeing level interacted with DMS, with simple effects analyses indicating that expert IDM self-efficacy was higher than ADM self-efficacy; conversely, novice referees showed the opposite pattern, suggesting that experts were more confident in their IDM accuracy, possibly indicating a preference for intuitive processing in System 1. In contrast, novices displayed greater confidence in ADM, suggesting a preference for this processing style. However, overconfidence did not yield completely consistent results with self-confidence. Contrary to common sense notions, experts in DM penalties were not significantly more overconfident than novices. Instead, novices were significantly more overconfident than experts, consistent with studies in sports betting. For instance, sportswriters and coaches, considered "experts," did not predict the outcome of the second round of the 2002 FIFA World Cup more accurately than students, or "novices," despite claiming to rely on information from extensive search and analysis (Andersson et al., 2003). Similar results were reported in another study on predicting teams for the 2006 FIFA World Cup tournament, where experts were not more successful than novices but showed considerable confidence in their predictions (Andersson et al., 2009). According to Griffin and Tversky's (1992) explanation of the overconfidence bias, forecasters' reliance on information could contribute to this bias. For example, teams playing at home have a higher probability of winning a game than when playing away (Nilsson and Andersson, 2010), suggesting that information about the match venue has predictive validity. Thus, knowledgeable and experienced decision-makers are more likely to be overconfident than those with less expertise because they have more knowledge and evidence upon which to base their judgments (Erceg and Galić, 2014). An additional explanation for overconfidence pertains to how individuals integrate evidence relevant to DM. According to Griffin and Tversky (1992), evaluating the consequences of a particular DM involves synthesizing various pieces of evidence. In most cases, two dimensions of evidence can be distinguished: the strength of evidence (extremity) and the weight of evidence (predictive validity) (Erceg and Galić, 2014). The interplay between these dimensions determines causality in DM. While predictive validity reflects the probability of an event occurring, overconfidence typically arises from the strength of the evidence (Erceg and Galić, 2014). The combination of these factors elucidates why experts tend to exhibit excessive caution in their DM. In situations with low predictability, each increment of expert knowledge enhances the strength of the evidence but does not influence its weight (i.e., predictive validity) (Erceg and Galić, 2014). Consequently, experts may possess superior judgment capabilities, yet the unpredictable nature of the situation hinders experience from accurately reflecting the accuracy of DM. As a result, experts' overconfidence may be lower than that of novices, highlighting experts' "fear of knowing." The observed overconfidence among novices may reflect "ignorance without fear," underscoring individual differences among referees (Avugos et al., 2021). The higher OC for expert IDM calls compared to ADM calls suggests that experts have greater confidence in their IDM, whereas novices are unaffected by DMS. Moreover, experts were more confident in awarding penalties than in withholding them, whereas novices displayed the opposite trend, indicating a bias towards self-protection among novices. Experts' overconfidence in awarding penalties may also signify heightened assurance during critical moments. Conversely, novices' overconfidence in not awarding penalties may serve as a form of self-protection.

Limitations

The present study had some limitations. Firstly, IDM and ADM did not have a well-defined time cutoff point in the temporal processing process, and there existed a lack of consistent empirical evidence to delineate the transition from IDM to ADM in a sports context. In real-world referee DM situations where both systems may operate concurrently, disentangling the two in laboratory settings might pose a great challenge. Since this study draws upon prior sports DM studies, such as presentations of handball game contexts for 2000 ms (Tenenbaum et al., 1993), soccer game contexts for 2,000 ms (McMorris and Graydon, 1996), and basketball game contexts for 1,000 ms (Tenenbaum et al., 1999), and integrates insights from national-level referees, it is an unprecedented attempt to limit IDM to 1,500 ms and ADM to 4,000 ms. Additionally, slow-motion replay DM videos were played back at double the original speed, which was closer to the IDM requirements, i.e., rapid processing while disregarding intricate details. However, how exactly to separate IDM from ADM according to the specific DM task requires continuous research by researchers in the field of motion science. Furthermore, drawing from findings in other research domains (Calabretta et al.,

2017), future studies in sports should explore the interplay between IDM and ADM across athletes, coaches, and referees (Bossard et al., 2022).

Secondly, there are two main paradigms in overconfidence measurement: confidence in binary decisions and interval prediction formats (Erceg and Galić, 2014). The classic method involves presenting participants with a series of questions, each offering two alternative answers. Participants are tasked with selecting the correct answer and providing their confidence level, with overconfidence inferred when the actual percentage of correct answers falls below the participant's stated confidence level. The second paradigm requires participants to specify the range of intervals within which they believe the correct answer lies in a given DM scenario, along with their associated probability. For example, a participant might state, "I am 90% confident that the population of Zagreb, Croatia, falls between 700,000 and 1,000,000" (Erceg and Galić, 2014). Both paradigms can detect individuals who overestimate the accuracy of their judgments and thus quantify overconfidence. While the present study explored overconfidence in referees' yellow card DM using the former paradigm, it is important to note that both paradigms rely on subjective reports from participants, which may be prone to inaccuracies and biases. Consequently, the measurement of overconfidence remains a subject of considerable debate. Therefore, future research should explore the use of more objective indicators to assess individual characteristics such as overconfidence.

Thirdly, several studies have demonstrated the significant impact of different video playback speeds on referees' DM under controlled laboratory conditions (Put et al., 2016; Spitz et al., 2017, 2018; Jochim et al., 2018; Del Campo and Martín, 2020; Vater et al., 2024). Research on the impact of slow-motion replay and real-time video playback on referees' DM regarding penalties has consistently revealed that referees tend to issue more severe penalties (including red or yellow cards) when viewing incidents in slow motion compared to real-time (Jochim et al., 2018; Spitz et al., 2018). Moreover, accuracy rates were found to be higher for decisions made using slow-motion replay (67%) compared to real-time viewing (56%) (Spitz et al., 2017). Contrarily, studies have shown that normal-speed playback resulted in higher ACCs for penalty decisions compared to 3× fast playback (Del Campo and Martín, 2020), and even slow-motion videos demonstrated higher DM accuracy than VR scenes (Vater et al., 2024). In contrast to the aforementioned findings, Put et al. (2016), in a study on offside penalty DM video simulation tasks, concluded that real-time and faster video conditions resulted in higher DM accuracy compared to slower video conditions. Video playback speed is an important variable, albeit with both positive and negative effects on penalty DM performance. In this study, high-definition (HD) playback video served as ADM material, while video playback at double the speed was used as IDM material. It is plausible that the confounding variable of video playback speed may have influenced the DM performance results, and future experiments may consider treating video playback speed as a covariate.

Lastly, because this study was a tightly controlled laboratory study, the entire experiment was tested in a laboratory setting. The referee's decision-making was not affected by the numerous variables (influence factors) that occur in the real situation (i.e., during a match), such as the presence of the public, the position of the referees in the field, the home advantage, team ranking, etc. Therefore, while internal validity is guaranteed, external validity will inevitably be reduced, and the ecological validity of stimulus–response-type laboratory experimental studies has always been a pressing issue for sports scientists. The conclusions in this study are limited to laboratory situations, so extrapolating the findings of the study to refereeing decision-making in real soccer matches has to be approached with caution. In addition, the referee's decision-making is now supported by video assistant referees (VARs), so some referee penalty decisions can be made later in the game after video viewing, and although communicating with VARs affects the flow and spectacle of the game, it does reduce the number of incorrect and missed calls in the game.

Recommendations

The study on soccer referees' yellow card decision-making has practical implications for training and performance improvement. Training programs should focus on analytical decision-making skills, encourage slower decision-making for accuracy, and include modules on managing overconfidence. Experience and Confidence: Expert referees have higher confidence in decisions. Novices should focus on building confidence through practice. Psychological Support: Referees need access to support and coping strategies for high-pressure situations. Feedback and Evaluation: Regular feedback helps referees understand their performance and areas for improvement. Education on Cognitive Biases: Training on cognitive biases can help referees be aware of decision-making pitfalls. Strategic Use of Intuition: Training should teach when to trust intuition and when to use a more analytical approach. Encourage Reflection and Learning: Debriefings and reflection sessions help referees learn from decisions and improve.

Conclusion

This study confirmed that novice referees' ADM penalty performance was superior to intuitive penalty performance in a soccer yellow card penalty DM task, while expert referees were not affected by DMS. In the yellow card offside penalty DM situation, both expert and novice referees showed overconfidence, and the degree of overconfidence was significantly higher in experts than in novices. Expert referees were more likely to be overconfident during IDM. They were more overconfident than non-yellow-card DM in awarding yellow-card DM, while novices were more overconfident than yellow-card DM in non-yellow-card DM situations. In conclusion, this study found that soccer referees were more likely to be overconfident in the yellow-card awarding DM task. The slower the referee's DM, the more accurate it is, and the higher the referee's level, the faster the referee's DM, leading to increased confidence until overconfidence arises.

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 Shenyang University of Sport 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

HW: Writing – original draft, Writing – review & editing. CZ: Methodology, Writing – review & editing. ZJ: Methodology, Writing – review & editing. XL: Methodology, Writing – review & editing. LW: Writing – review & editing, Writing – original draft.

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Conflict of interest

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

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Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Fernando Jorge Santos,
Instituto Politécnico de Setúbal (IPS), Portugal
Wei Sun,
Shandong Sport University, China

*CORRESPONDENCE
Liang Cheng
xuelilantian@163.com

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The work stress, occupational burnout, coping strategies and organizational support of elite sports coaches in Sichuan Province: the mediating role of organizational support

Liang Yu[1] and Liang Cheng[1,2,3]*

[1]Human Movement Science, Sichuan Sports College, Chengdu, China, [2]Sichuan Academy of Chinese Medicine Sciences, Chengdu, China, [3]School of Sports Medicine and Health, Chengdu Sport University, Chengdu, China

Objective: This study investigated the relationships between job pressure, occupational burnout, organizational support and coping strategies among competitive sports coaches in Sichuan Province, China. It also assesses the impact of job pressure on occupational burnout and the mediating roles of organizational support and coping strategies.

Methods: A survey was conducted with 207 competitive sports coaches from Sichuan Province, China. Basic information and data on job pressure, occupational burnout, organizational support and coping strategies were collected. Correlations between variables were analyzed, and a theoretical model for hypothesizing the mediating effects was established. A multiple regression model was used to predict the relationships between occupational burnout and job pressure, organizational support and coping strategies.

Results: (1) Job pressure was significantly positively correlated with occupational burnout ($R = 0.436$, $p < 0.001$) and negative coping ($R = 0.389$, $p < 0.001$) but significantly negatively correlated with organizational support ($R = -0.503$, $p < 0.001$). Occupational burnout was significantly negatively correlated with academic title ($R = -0.158$, $p = 0.023$) and organizational support ($R = -0.349$, $p < 0.001$) but significantly positively correlated with negative coping ($R = 0.440$, $p < 0.001$). Organisational support was significantly positively correlated with positive coping ($R = 0.222$, $p = 0.001$) but significantly negatively correlated with negative coping ($R = -0.207$, $p = 0.003$). (2) Mediating effects: Job pressure indirectly affects occupational burnout via organizational support and negative coping strategies. (3) Multiple regression: Y_1 (Job Pressure) = 69.262 + 1.172 × Emotional Exhaustion −2.231 × Emotional Support +1.041 × Negative Coping −6.554 × Academic Title (from high to low). Y_2 (Occupational Burnout) = 25.609 + 0.141 × Job Pressure − 0.306 × Organisational Support +0.620 × Negative Coping −2.097 × Academic Title.

Conclusion: Job pressure is a significant factor leading to occupational burnout among competitive sports coaches in Sichuan Province, China, and factors such as role, interpersonal relationships and career development are closely related to occupational burnout. The sense of organizational support and negative coping strategies play a mediating role between job pressure and occupational burnout. Reducing emotional exhaustion and negative coping, enhancing

emotional support and improving the academic titles of coaches can help to reduce job pressure and occupational burnout among competitive sports coaches in Sichuan Province.

KEYWORDS

wellbeing, coping strategies, stress management, athlete training, mental health

1 Introduction

Occupational burnout, an extreme manifestation of job pressure, represents the response of the body to stress (Yang et al., 2023; Altaş et al., 2024). When individuals are confronted with job pressure, they experience psychological and physical tension. Against the backdrop of China's competitive sports system, which operates under a 'national system' (Cheng et al., 2022), coaches in competitive sports face numerous job pressures, particularly during the quadrennial National Games of China. This event involves competition and comparison of sports achievements across provinces, and pressure stems not only from the job itself but also from the stringent demands and high standards set by higher authorities and expectations regarding the guidance, training and competitive outcomes of athletes (Dehghansai et al., 2023; Sankey et al., 2023). Additionally, the financial income and personal advancement of coaches often depend on the competitive performance of the athletes they coach (Orunbayev, 2023). Studies have shown a strong correlation between job pressure and occupational burnout; the greater the job pressure is, the greater the likelihood that coaches will experience occupational burnout (Richards et al., 2019; Schaffran et al., 2019). A sense of organizational support plays a significant role in the relationship between job pressure and occupational burnout (Liu et al., 2021; Xu and Yang, 2021; Irfan et al., 2023). When coaches perceive greater support from the organization, they are more inclined to adopt positive coping strategies, which can mitigate the adverse effects of job pressure (Olsen et al., 2020; Potts et al., 2023). Conversely, when coaches perceive less organizational support, they may resort to negative coping strategies, which can worsen their negative emotional state and intensify job pressure (Norris et al., 2017; Lee and Chelladurai, 2018).

To the best of our knowledge, only two studies have reported on the relationship between job pressure and occupational burnout among Chinese competitive sports coaches (Mellor et al., 2015; Men et al., 2015). A survey conducted in 2015 of 302 coaches across 10 cities in China revealed that the overall condition of occupational burnout among Chinese coaches was greater than moderate, with significant manifestations of emotional exhaustion and a lack of achievement (Men et al., 2015). A measurement of 605 Chinese coaches in 2020 revealed that job pressure among coaches is generally high and that the issue of occupational burnout is severe (Mellor et al., 2015). However, the aforementioned studies did not provide appropriate improvement strategies. The primary reason is the complexity of the relationship between job pressure and occupational burnout, which necessitates an in-depth examination and verification of mediating and moderating variables (Baquero, 2023; Jeong et al., 2024). The factors that influence the relationship between job pressure and occupational burnout among coaches must be explored to effectively prevent and control occupational burnout in stress management, which can assist coaches better cope with job pressure.

Sichuan Province is not only a populous province, with a permanent population of 83.675 million people in 2024, ranking fifth in China; it is also an important province for competitive sports, with its competitive sports achievements ranking sixth nationwide. However, coaches in Sichuan are under considerable job pressure. With the aim of addressing this issue, we conducted a field survey of 207 competitive sports coaches in Sichuan Province.

The purpose of this study is to propose effective solutions to alleviate job pressure and occupational burnout among coaches. The results have significant theoretical and practical implications for enhancing the wellbeing of coaches, optimizing the management of sports organizations, improving the training outcomes of athletes and promoting the healthy development of the sports industry. Building on prior studies that have established a correlation between job pressure and occupational burnout, our hypotheses explore the nuanced relationships between these variables and the role of organizational support and coping strategies. The study hypotheses are as follows: H1: job pressure positively affects occupational burnout; H2: organizational support negatively moderates the relationship between job pressure and occupational burnout; H3: negative coping strategies positively moderate the relationship between job pressure and occupational burnout; and H4: academic titles are negatively correlated with occupational burnout.

2 Materials and methods

2.1 Participants

This study involving humans were approved by the study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Sichuan Sports College (2023.12). All the participants have signed an informed consent form in all participants. As of April 2024, Sichuan Province has a total of 331 competitive sports coaches: 30 senior coaches, 96 associate senior coaches, 103 intermediate coaches and 102 junior coaches. We conducted a field survey via random sampling, and 207 participants were ultimately included in the study, resulting in an effective survey response rate of 62.5% (Table 1). These coaches come from 21 prefecture-level cities and states in Sichuan Province and cover 15 Olympic sports categories (including track and field, basketball, volleyball, and football), suggesting a broad demographic representation. Among the surveyed coaches, 149 are males and 58 are females. The average age is 41.1 ± 5.5 years, and the average coaching tenure is 13.7 ± 6.5 years. In terms of length of tenure, 32 coaches have 5 years or less of experience (15.5%), 59 coaches have

TABLE 1 Basic information of the study participants.

Indicator	Male	Female	Total	*p*
N	149	58	207	
Age (years)	41.7 ± 9.5	39.7 ± 8.0	41.1 ± 5.5	0.169
Height (cm)	167.2 ± 5.6	177.3 ± 6.2	172.3 ± 6.7	0.012
Weight (kg)	63.6 ± 9.2	76.5 ± 8.6	70.2 ± 11.3	<0.01
Coaching experience (years)	14.5 ± 8.3	11.8 ± 7.3	13.7 ± 6.5	0.031
5 years and below (*n*, %)	20 (13.4%)	12 (20.7%)	32 (15.5%)	
6–10 years (*n*, %)	39 (26.2%)	20 (34.5%)	59 (28.5%)	
11–15 years (*n*, %)	33 (22.1%)	14 (24.1%)	47 (22.7%)	
16–20 years (*n*, %)	27 (18.1%)	4 (6.9%)	31 (15.0%)	
21 years and above (*n*, %)	30 (20.1%)	8 (13.8%)	38 (18.4%)	
Junior coach	52 (34.9%)	15 (25.9%)	67 (32.4%)	
Intermediate coach	56 (37.6%)	24 (41.3%)	80 (38.6%)	
Associate senior coach	31 (20.8%)	14 (24.1%)	45 (21.7%)	
Senior coach	10 (6.7%)	5 (8.6%)	15 (7.2%)	

6–10 years of experience (28.5%), 47 coaches have 11–15 years of experience (22.7%), 31 coaches have 16–20 years of experience (15.0%), and 38 coaches have 21 years or more of experience (18.4%).

In terms of the distribution of academic titles, 67 are junior coaches (32.4%), 80 are intermediate coaches (38.6%), 45 are associate senior coaches (21.7%), and 15 are senior coaches (7.2%).

2.2 Questionnaire survey

This study employed questionnaires tailored to the Chinese coaching population to accurately measure the job pressure, occupational burnout, perceived organizational support and coping strategies of coaches.

2.2.1 Job pressure

The Occupational Stress Indicator, designed by Cooper et al. (1988) and consisting of 41 items, was revised to suit the Chinese coaching population (Mellor et al., 2015). Each item was rated on a five-point scale ranging from 'completely disagree' to 'completely agree' and was scored from 0 to 4. Eight dimensions were considered: job condition (items 1–4), role (items 5–9), interpersonal relationships (items 10–17), career development (items 18–20), job tasks (items 21–27), management affairs (items 28–34), personal accomplishment (items 35–39) and external competition (items 40 and 41). Higher scores indicate greater perceived job pressure by the coaches. Specified for the Chinese coaching population, our Cronbach's α coefficient for this questionnaire was 0.868, with a composite reliability of 0.870 (Mellor et al., 2015).

2.2.2 Occupational burnout questionnaire

A Chinese version of the Burnout Questionnaire revised by Guo and Xu (2017) from Maslach's questionnaire (Schutte et al., 2000) consisting of 15 items was rated on a seven-point scale. The questionnaire included three dimensions: emotional exhaustion (items 1–5), reduced efficacy (items 6–11) and depersonalisation (items 12–15). The emotional exhaustion and depersonalisation dimensions were scored in the range of 0 to 6, whereas the reduced efficacy dimension was scored in reverse from 6 to 0. Higher scores indicate a greater degree of occupational burnout. Specified for the Chinese coaching population, our Cronbach's α coefficient for this questionnaire was 0.892, with a composite reliability of 0.881 (Men et al., 2015).

2.2.3 Perceived organizational support scale

The scale, developed by American psychologist Eisenberger et al. (1986) and consisting of 12 items, was rated on a five-point scale ranging from 'very inconsistent' to 'fully consistent' and scored from 0 to 4. Four dimensions were considered: systemic support (items 1–3), emotional support (items 4–6), instrumental support (items 7–9), and peer support (items 10–12). Higher scores indicate a greater perceived level of organizational support by the coaches. Specified for the Chinese coaching population, our Cronbach's α coefficient for this questionnaire was 0.895, with a composite reliability of 0.821 (Mellor et al., 2015).

2.2.4 Coping strategy scale

This simplified coping strategy questionnaire (Zhao et al., 2022) tailored for the Chinese population included 20 items, each rated on a four-point scale ranging from 'never adopted' to 'frequently adopted' and scored from 0 to 3. The questionnaire includes two dimensions: positive coping (items 1–12) and negative coping (items 13–20). Higher scores in the positive coping dimension indicate greater use of positive coping strategies, whereas higher scores in the negative coping dimension indicate greater use of negative coping strategies. Specified for the Chinese coaching population, our Cronbach's α coefficient for this questionnaire was 0.901, with a composite reliability of 0.866 (Mellor et al., 2015).

2.3 Psychometric assessment of the questionnaire

Cronbach's α was used to test the reliability of the 207 valid questionnaires. An α value of ≥ 0.70 indicates high reliability, $0.35 \leq \alpha < 0.70$ is acceptable, and $\alpha < 0.35$ indicates low reliability

(Cheng et al., 2023). The reliability test showed an α of 0.780. In terms of assessing the test–retest reliability, a random sample of 20% of the participants was retested after 7 days. The Pearson's correlation coefficient for each indicator was $r \geq 0.812$, indicating a high degree of reliability in the questionnaire.

2.4 Statistical analysis

Statistical analyses were performed using SPSS version 20 and the SPSS macro PROCESS. All variables were initially tested for a normal distribution (Cheng et al., 2024). For normally distributed data, *t*-test was used to compare parameters between male and female participants; otherwise, the Mann–Whitney *U*-test was applied. Then, Spearman correlation analysis was used to examine the correlations among the variables. Hayes' macro PROCESS in SPSS was employed to test the hypotheses of the theoretical model, and the bootstrapping method was used to estimate the standard errors of simple effects. In the case of testing indirect effects, a 95% bootstrap confidence interval that does not include zero indicates the presence of mediation. Finally, multiple regression models were constructed with either occupational burnout or job pressure as the dependent variables while controlling for confounding factors such as age, gender, years of vocational teaching and academic title to predict the relationships between occupational burnout or job pressure and other factors. The significance level was set at $\alpha = 0.05$.

3 Results

Initially, the measured data were normally distributed. Comparisons of parameters between male and female participants were conducted via t-tests, and no statistically significant differences in the indices were detected ($p > 0.05$) (Table 2). The results of the Spearman correlation analysis are shown in Table 3 and Supplementary Table S1.

The results of the correlation analysis are as follows: academic title (from high to low) was significantly negatively correlated with burnout total scores ($R = -0.158$, $p = 0.023$), emotional exhaustion (a subscale of burnout, $R = -0.169$, $p = 0.015$), alienation (a subscale of burnout, $R = -0.189$, $p = 0.006$) and instrumental support (a subscale of organizational support, $R = -0.151$, $p = 0.030$). Work pressure was significantly positively correlated with occupational burnout ($R = 0.436$, $p < 0.001$) and negative coping ($R = 0.389$, $p < 0.001$) but significantly negatively correlated with organizational support ($R = -0.503$, $p < 0.001$). Further correlation analysis of the eight subscales of work pressure with the three subscales of occupational burnout, negative coping and the four subscales of organizational support revealed that job security was significantly positively correlated with emotional exhaustion ($R = 0.151$, $p = 0.030$) but significantly negatively correlated with emotional support ($R = -0.305$, $p < 0.001$) and peer support ($R = -0.184$, $p = 0.008$). Role was significantly positively correlated with emotional exhaustion ($R = 0.322$, $p < 0.001$), alienation ($R = 0.343$, $p < 0.001$) and negative coping ($R = 0.291$, $p < 0.001$) but significantly negatively correlated

TABLE 2 Statistical results of participants' job pressure, occupational burnout, organizational support, and coping strategies.

Indicator	Male	Female	Total	Gender comparison (*p*-value)
Job pressure (score)	94.72 ± 23.55	92.79 ± 17.43	94.18 ± 22.03	0.573
Job condition	13.54 ± 3.28	13.78 ± 2.15	13.60 ± 3.01	0.610
Role	5.07 ± 4.46	4.88 ± 3.41	5.02 ± 4.20	0.739
Interpersonal relationships	13.26 ± 6.89	12.38 ± 6.35	13.01 ± 6.75	0.386
Career development	6.40 ± 3.72	6.38 ± 3.32	6.39 ± 3.61	0.975
Job tasks	22.41 ± 5.18	23.24 ± 3.64	22.64 ± 4.81	0.266
Management affairs	18.40 ± 4.55	17.62 ± 3.58	18.18 ± 4.32	0.248
Personal achievement	10.64 ± 3.79	9.74 ± 2.87	10.39 ± 3.58	0.104
External competition	5.01 ± 2.05	4.78 ± 1.64	4.94 ± 1.95	0.447
Occupational burnout (score)	27.54 ± 11.39	28.86 ± 10.26	27.91 ± 11.10	0.445
Emotional exhaustion	14.63 ± 6.44	15.57 ± 5.18	14.89 ± 6.12	0.281
Reduced efficacy	5.32 ± 4.42	5.88 ± 2.26	5.48 ± 4.68	0.444
Alienation	7.59 ± 5.33	7.41 ± 4.53	7.54 ± 5.12	0.825
Perceived organizational support (score)	33.01 ± 9.51	33.78 ± 7.93	33.23 ± 9.10	0.590
Systemic support	8.30 ± 2.64	8.43 ± 2.07	8.33 ± 2.50	0.727
Emotional support	8.07 ± 2.90	7.95 ± 2.48	8.04 ± 2.79	0.772
Instrumental support	7.64 ± 3.13	8.07 ± 2.43	7.76 ± 2.95	0.304
Peer support	9.00 ± 2.12	9.33 ± 1.80	9.09 ± 2.04	0.302
Positive coping strategies (score)	24.41 ± 6.44	23.98 ± 6.24	24.29 ± 8.19	0.668
Negative coping strategies (score)	8.11 ± 4.92	8.40 ± 4.21	6.39 ± 4.73	0.701

TABLE 3 Correlations of job pressure, occupational burnout, organizational support, and coping strategies among participants ($N = 207$).

		Coaching tenure	Age	Academic title	Job pressure	Occupational burnout	Organisational support	Positive coping	Negative coping
Job pressure	R	0.051	−0.028	0.131		0.436	−0.503	0.075	0.389
	p	0.466	0.691	0.060		0.000	0.000	0.285	0.000
Occupational burnout	R	0.071	0.061	−0.158	0.436		−0.349	−0.052	0.440
	p	0.309	0.380	0.023	0.000		0.000	0.458	0.000
Organisational support	R	0.051	0.085	−0.121	−0.503	−0.349		0.222	−0.207
	p	0.470	0.226	0.082	0.000	0.000		0.001	0.003

with supervisory support ($R = -0.408$, $p < 0.001$), emotional support ($R = -0.479$, $p < 0.001$), instrumental support ($R = -0.468$, $p < 0.001$) and peer support ($R = -0.426$, $p < 0.001$). The sense of interpersonal relationships was significantly positively correlated with emotional exhaustion ($R = 0.363$, $p < 0.001$), alienation ($R = 0.408$, $p < 0.001$) and negative coping ($R = 0.280$, $p < 0.001$) but significantly negatively correlated with supervisory support ($R = -0.425$, $p < 0.001$), emotional support ($R = -0.429$, $p < 0.001$), instrumental support ($R = -0.441$, $p < 0.001$) and peer support ($R = -0.387$, $p < 0.001$). Career development was significantly positively correlated with emotional exhaustion ($R = 0.373$, $p < 0.001$), alienation ($R = 0.359$, $p < 0.001$) and negative coping ($R = 0.295$, $p < 0.001$) but significantly negatively correlated with supervisory support ($R = -0.492$, $p < 0.001$), emotional support ($R = -0.530$, $p < 0.001$), instrumental support ($R = -0.501$, $p < 0.001$) and peer support ($R = -0.471$, $p < 0.001$). The sense of job tasks was significantly positively correlated with emotional exhaustion ($R = 0.310$, $p < 0.001$) and negative coping ($R = 0.232$, $p < 0.001$) but significantly negatively correlated with supervisory support ($R = -0.224$, $p = 0.001$), emotional support ($R = -0.247$, $p < 0.001$), instrumental support ($R = -0.302$, $p < 0.001$) and peer support ($R = -0.194$, $p = 0.005$). The sense of management affairs was significantly positively correlated with emotional exhaustion ($R = 0.166$, $p = 0.017$) and negative coping ($R = 0.240$, $p < 0.001$) and showed no significant correlation with the various indicators of organizational support. Self-accomplishment was significantly positively correlated with emotional exhaustion ($R = 0.380$, $p < 0.001$), alienation ($R = 0.374$, $p < 0.001$) and negative coping ($R = 0.383$, $p < 0.001$) but negatively correlated with supervisory support ($R = -0.246$, $p < 0.001$). External competition was significantly positively correlated with emotional exhaustion ($R = 0.279$, $p < 0.001$), alienation ($R = 0.247$, $p < 0.001$) and negative coping ($R = 0.332$, $p < 0.001$) but significantly negatively correlated with supervisory support ($R = -0.237$, $p < 0.001$), emotional support ($R = -0.264$, $p < 0.001$), instrumental support ($R = -0.307$, $p < 0.001$) and peer support ($R = -0.322$, $p < 0.001$).

Occupational burnout was significantly negatively correlated with organizational support ($R = -0.349$, $p < 0.001$) but significantly positively correlated with negative coping ($R = 0.440$, $p < 0.001$). Further correlation analysis of the three subscales of occupational burnout with the four subscales of organizational support and negative coping revealed that emotional exhaustion was significantly negatively correlated with supervisory support ($R = -0.270$, $p < 0.001$), emotional support ($R = -0.246$, $p < 0.001$), instrumental support ($R = -0.271$, $p < 0.001$) and peer support ($R = -0.256$, $p < 0.001$) but significantly positively correlated with negative coping ($R = 0.390$, $p < 0.001$). The feeling of inefficacy was significantly negatively correlated with peer support ($R = -0.139$, $p = 0.046$). Alienation was significantly negatively correlated with supervisory support ($R = -0.323$, $p < 0.001$), emotional support ($R = -0.235$, $p = 0.001$), instrumental support ($R = -0.224$, $p = 0.001$) and peer support ($R = -0.274$, $p < 0.001$) but significantly positively correlated with negative coping ($R = 0.398$, $p < 0.001$). Organisational support was significantly positively correlated with positive coping ($R = 0.222$, $p = 0.001$) but significantly negatively correlated with negative coping ($R = -0.207$, $p = 0.003$). Further correlation analysis of the four subscales of organizational support with positive and negative coping revealed that supervisory support was significantly positively correlated with positive coping ($R = 0.200$, $p = 0.004$) but significantly negatively correlated with negative coping ($R = -0.230$, $p = 0.001$). Emotional support was significantly positively correlated with positive coping ($R = 0.259$, $p < 0.001$) but significantly negatively correlated with negative coping ($R = -0.176$, $p = 0.011$). Instrumental support was significantly positively correlated with positive coping ($R = 0.154$, $p = 0.027$) but significantly negatively correlated with negative coping ($R = -0.146$, $p = 0.035$). Peer support was significantly positively correlated with positive coping ($R = 0.210$, $p = 0.002$) but significantly negatively correlated with negative coping ($R = -0.139$, $p = 0.045$).

This study examined the parallel mediating effects of organizational support and negative coping styles on the relationship between job pressure and occupational burnout (Figure 1). In terms of the total effect, the overall impact of job pressure (X) on occupational burnout (Y) was 0.2393, indicating that the influence of X on Y, without considering the mediating roles of organizational support and negative coping (M1 and M2), was significant at 0.2393 ($p < 0.01$). The direct influence of X on Y, after accounting for organizational support and negative coping, was 0.1237, which was also significant ($p < 0.01$). Finally, regarding the indirect effect (mediation effect), the mediated impact of X on Y through M1 and M2 was 0.1156, with a bootstrap standard error of 0.0262. The 95% confidence interval did not contain zero (i.e., the bootstrap lower limit confidence interval [BootLLCI] was 0.0676, and the upper limit [BootULCI] was 0.1702), indicating that the mediating effect was significant. The direct effect of X on Y was 0.2393. The indirect effect, which is the difference between the total and direct effects [0.2393–0.1237 = 0.1156], signifies that M1 and M2 mediate the relationship between X and Y, with this portion of the effect being transmitted through the mediating variables M1 and M2. These findings suggest that the impact of job pressure on occupational burnout among competitive sports coaches is moderated by organizational support and negative coping strategies.

This study constructed a multiple regression model with job pressure as the dependent variable and occupational burnout,

organizational support and coping strategies as the independent variables while considering confounding factors such as age, gender, years of vocational teaching and academic title. However, a regression model could not be established. Upon further consideration of the subscales of occupational burnout, organizational support and coping strategies, the results indicated that job pressure [$F_{(4,202)} = 38.974$, $p < 0.001$] was statistically significant, with a constant value of 69.262. Multiple regression revealed relationships for emotional exhaustion ($\beta = 1.172$, $p < 0.001$), emotional support ($\beta = -2.231$, $p < 0.001$), negative coping ($\beta = 1.041$, $p < 0.001$) and academic title ($\beta = -6.554$, $p = 0.003$). The regression equation for predicting the job pressure scores of competitive sports coaches was $Y_1 = 69.262 + 1.172 \times$ Emotional Exhaustion $-2.231 \times$ Emotional Support $+1.041 \times$ Negative Coping $-6.554 \times$ Academic Title.

In another model, occupational burnout were taken as the dependent variable and job pressure, and organizational support and coping strategies were taken as the independent variables, while controlling for confounding factors such as age, gender, years of vocational teaching and academic title. The results showed that occupational burnout [$F_{(4,144)} = 24.112$, $p < 0.001$] was statistically significant, with a constant value of 25.609. Moreover, multiple regression relationships for job pressure ($\beta = 0.141$, $p < 0.001$), organizational support ($\beta = -0.306$, $p < 0.001$), negative coping strategies ($\beta = 0.620$, $p < 0.001$) and academic title ($\beta = -2.097$, $p = 0.011$, where the first to fourth academic titles represent full professor, associate professor, lecturer and assistant lecturer), were detected. The regression equation for predicting the occupational burnout scores of competitive sports coaches was $Y_2 = 25.609 + 0.141 \times$ Job Pressure $- 0.306 \times$ Organisational Support $+0.620 \times$ Negative Coping $-2.097 \times$ Academic Title.

4 Discussion

The purpose of this study was to explore the relationships between job pressure, occupational burnout, perceived organizational support and coping strategies among competitive sports coaches in Sichuan Province and to evaluate the impact of job pressure on occupational burnout, as well as the mediating roles of organizational support and coping strategies. All four research hypotheses were supported by the findings of this study.

This study confirmed Hypothesis 1: job pressure positively affects occupational burnout. The correlation analysis revealed a significant positive correlation between job pressure and occupational burnout ($R = 0.436$), indicating that the greater the job pressure is, the greater the level of occupational burnout experienced by the coaches. Furthermore, the positive standardized regression coefficient ($\beta = 0.141$) for job pressure in the multiple regression analysis confirmed that job pressure positively influences occupational burnout. Additionally, when all eight subdimensions of job pressure were used as independent variables and occupational burnout scores were used as the dependent variable, the model results showed that all subdimensions of job pressure were positively correlated with occupational burnout scores. This finding supports the hypothesis that job pressure positively affects occupational burnout. Moreover, the mediating effects found in this study indicate that organizational support not only directly affects occupational burnout but also plays a role in moderating the relationship between job pressure and occupational burnout. When the sense of organizational support is low, the positive correlation between job pressure and the occupational burnout of coaches intensifies. Conversely, when the sense of organizational support is high, the positive correlation between job pressure and occupational burnout is attenuated. This finding provides a new perspective for understanding and managing job pressure and occupational burnout among coaches. In practice, we should focus on enhancing the job support perceived by coaches to alleviate their job pressure and burnout, thereby improving their work efficiency and job satisfaction.

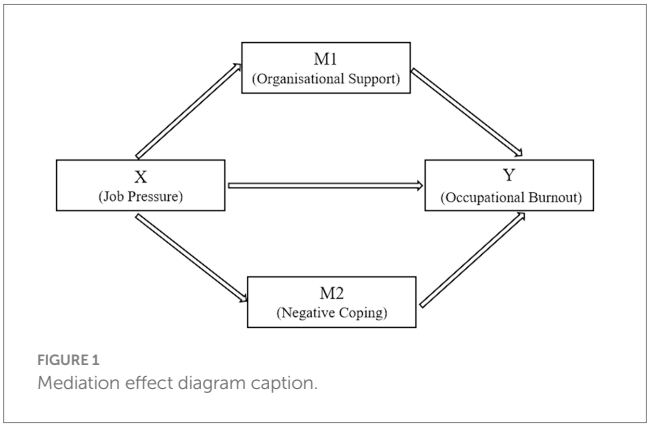

FIGURE 1
Mediation effect diagram caption.

The study findings are consistent with the results of surveys conducted in 2015 on 302 competitive sports coaches (Men et al., 2015) and in 2020 on 605 competitive sports coaches (Mellor et al., 2015) in China, which revealed a significant positive correlation between job pressure and occupational burnout among coaches. The results of the current study, which investigated competitive sports coaches in Sichuan Province, China, align with the aforementioned results (Mellor et al., 2015; Men et al., 2015). We analyzed potential reasons for this correlation, including the association of several factors. Firstly, competitive sports coaches are required not only to master a vast amount of subject-specific knowledge related to their discipline but also to apply this interdisciplinary knowledge to solve various problems encountered in training (Siwik et al., 2015). This long-term commitment and effort can inevitably lead to a state of extreme fatigue. Secondly, coaches are overburdened by multiple roles in both their professional and personal lives, dealing with a multitude of complex relationships. The sustained pressure associated with these roles can lead to emotional exhaustion, physical and mental fatigue and even a sense of helplessness toward one's work (Altfeld et al., 2018). Although job pressure among coaches can partially explain their occupational burnout, the level of burnout experienced by coaches at the same pressure level is not uniform. When coaches lack specific resources, their job demands are not fully met, or when they do not receive the expected rewards, they may experience occupational burnout (Carson et al., 2018).

This study confirmed Hypothesis 2: perceived organizational support negatively moderates the relationship between job pressure and occupational burnout. Correlation analysis indicated a significant negative correlation between job pressure and organizational support ($R = -0.503$), suggesting that as job pressure increases, perceived organizational support decreases. Additionally, the subdimensions of organizational support (systemic support, emotional support, instrumental support and peer support) were negatively correlated

with the subdimensions of job pressure, demonstrating the moderating role of organizational support in the relationship between job pressure and occupational burnout. This finding is consistent with the study results of Mellor et al. (2015), who proposed that organizational support has a moderating effect on the relationship between job pressure and job burnout among coaches, with coping strategies serving as a mediating variable. Several factors may be involved based on our analysis. Firstly, organizational support can function as a buffering resource for coaches facing job pressure (Knight et al., 2015). When coaches perceive support from their organization, they feel more valued and resourceful, which can help mitigate the direct impact of job pressure on occupational burnout. According to conservation of resources theory, organizational support is a resource that can help coaches maintain a balance of resources when confronted with job pressure (Lawrence and Callan, 2011). When such support is diminished, coaches may perceive a lack of resources, thereby increasing the risk of occupational burnout. Secondly, organizational support can assist coaches in addressing job demands. Coaches who feel a high level of organizational support are likely to view job pressure as a manageable challenge rather than an insurmountable obstacle (Kristiansen and Roberts, 2010). Furthermore, organizational support may reduce the sense of emotional exhaustion among coaches, a key dimension of occupational burnout (Smollan, 2017), by providing emotional solace and practical assistance; it can also enhance the sense of achievement of coaches and reduce their feelings of alienation from their work. Finally, organizational support can indirectly alleviate job pressure by improving the work environment and conditions, such as by providing additional resources, training and career development opportunities.

The present study confirmed Hypothesis 3: negative coping strategies positively moderate the relationship between job pressure and occupational burnout. Correlation analysis revealed a significant positive correlation between job pressure and negative coping strategies ($R = 0.389$), indicating that as job pressure increases, coaches are likely to adopt negative coping strategies. Additionally, negative coping was significantly positively correlated with all eight subdimensions of job pressure, further supporting Hypothesis 3. Moreover, the positive standardized regression coefficient ($\beta = 0.620$) for negative coping strategies in the multiple regression analysis further illustrates that these strategies intensify the impact of job pressure on occupational burnout. We analyzed potential reasons that may be associated with the following factors. Firstly, when coaches face job pressure, they may employ various coping strategies. Negative coping strategies, such as avoidance, self-blame or emotional venting, may provide short-term relief from stress but can exacerbate occupational burnout in the long term (Edú et al., 2022). Secondly, the cumulative effect of negative coping can increase the accumulation of psychological stress, thereby intensifying the emotional exhaustion and reduced sense of achievement associated with occupational burnout (Bakker and Vries, 2021). Furthermore, negative coping may deplete the psychological resources of an individual, as these strategies typically do not effectively resolve issues and may instead impose additional psychological burdens (Hershcovis et al., 2018). Coaches who resort to negative coping strategies may struggle with emotional regulation, hindering their recovery from job pressure and increasing their sense of burnout. Additionally, negative coping strategies may affect the satisfaction with the work environment of coaches, as they may feel incapable of effectively dealing with workplace challenges (Cho et al., 2021). Negative coping strategies can also reduce the social support coaches receive from colleagues or the organization, as these strategies may hinder effective communication and collaboration. The prolonged use of negative coping strategies may lower the self-efficacy of coaches, leading them to doubt their abilities, thus increasing the risk of occupational burnout. As a way of mitigating occupational burnout, sports organizations should consider providing training in coping strategies and psychological support to help coaches develop more effective stress management skills.

The present study confirmed Hypothesis 4: academic title is negatively correlated with occupational burnout, indicating that the higher the academic title is, the lower the level of occupational burnout. Correlation analysis revealed a significant negative correlation between academic title and the total score of occupational burnout, as well as its subdimensions (emotional exhaustion and depersonalisation), supporting the hypothesis that academic title is negatively associated with occupational burnout. Additionally, multiple regression analysis revealed a negative correlation between academic title and occupational burnout scores ($\beta = -2.097$), implying that coaches with lower academic titles (junior level) are at greater risk of occupational burnout than are those with higher academic titles (senior level). This finding may be related to the greater job pressure and less resource support faced by junior coaches. To our knowledge, no studies have reported on the relationship between academic titles and occupational burnout among competitive sports coaches in China, and our findings provide a basis for similar future research. We analyzed potential reasons that may be associated with the following factors. Firstly, junior coaches are in the early stages of their career development, a phase that is typically accompanied by greater uncertainty and challenges. Coaches need to invest more time and effort to enhance their coaching skills and professional status (Müller et al., 2020). Secondly, coaches with higher academic titles have greater status and greater authority within the organization, enabling them to better control their work environment and reduce job pressure. Furthermore, senior coaches who have achieved certain professional accomplishments and who have received organizational recognition experience a greater level of satisfaction, which can serve as a protective factor, reducing the risk of occupational burnout (Hill et al., 2021).

This study established multiple regression models with job pressure or occupational burnout scores as the dependent variables, taking into account confounding factors such as age, gender, years of vocational teaching and academic title, to predict the relationships between job pressure or occupational burnout and other factors. Our findings hold significant practical value for developing effective intervention measures and management strategies. The regression model for job pressure developed in this study was $Y_1 = 69.262 + 1.172 \times \text{Emotional Exhaustion} - 2.231 \times \text{Emotional Support} + 1.041 \times \text{Negative Coping} - 6.554 \times \text{Academic Title}$ (ranging from high to low). Thus, reducing emotional exhaustion and negative coping and enhancing emotional support and the academic titles of coaches can contribute to lowering job pressure. The regression model for occupational burnout developed in this study was $Y_2 = 25.609 + 0.141 \times \text{Job Pressure} - 0.306 \times \text{Organisational Support} + 0.620 \times \text{Negative Coping} - 2.097 \times \text{Academic Title}$. Therefore, increasing organizational support and the academic titles of coaches and reducing negative coping can help lower occupational burnout.

We recommend that sports organizations in Sichuan Province provide further support and opportunities for career advancement to coaches.

In light of the findings, this study offers several practical implications for the field of sports coaching. Firstly, it suggests that sports organizations should prioritize enhancing organizational support to alleviate job pressure and prevent burnout among coaches (Chang et al., 2024). Secondly, the development of targeted training programs aimed at improving coping strategies could be beneficial. Lastly, the recognition of the negative impact of job pressure on occupational burnout underscores the need for policy interventions that protect the well-being of coaches and promote a healthy work environment. These implications highlight the study's contribution to both the theoretical understanding of job pressure and burnout, as well as its practical utility in shaping sports management strategies.

5 Study limitations

This study has certain limitations. Firstly, although the mediation analysis showed that organizational support and negative coping styles play a mediating role between job pressure and occupational burnout, the mediating effect of positive coping strategies was not discussed. Future research may benefit from integrating positive coping strategies as a mediating variable to fully understand how coping strategies affect the relationship between job pressure and occupational burnout. Secondly, while our multiple regression model considered some confounding factors, other unidentified or uncontrolled confounding factors, such as personal values, job satisfaction and the work environment of the coaches, may be considered. Subsequent studies may focus on collecting more variables that can affect occupational burnout and controlling for them in the model. Finally, given the cross-sectional design of our study, causality could not be established. Future research will be designed as a longitudinal intervention study based on the findings of this study to better alleviate job pressure and occupational burnout among coaches.

6 Conclusion

Job pressure is a significant factor leading to occupational burnout among competitive sports coaches in Sichuan Province, China, and factors such as role, interpersonal relationships and career development are closely related to occupational burnout. Organisational support and negative coping strategies mediate the relationship between job pressure and occupational burnout. Reducing emotional exhaustion and negative coping and enhancing emotional support and the academic titles of coaches can help to lower job pressure and occupational burnout among competitive sports coaches in Sichuan Province.

Data availability statement

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

Ethics statement

This study involving humans were approved by the study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Sichuan Sports College (2023.12). All the participants have signed an informed consent form in all 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. 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

LY: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. LC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, 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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1437234/full#supplementary-material

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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Christopher A. Was,
Kent State University, United States
Yadan Li,
Shaanxi Normal University, China

*CORRESPONDENCE
Yuxiu He
✉ heyuxiu@hebtu.edu.cn

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Mind wandering is not always harmful in sports: the role of its content

Jieling Li[1,2,3], Chuangye Li[1], Shuangpeng Xue[1] and Yuxiu He[1,2,3]*

[1]Physical Education Postdoctoral Research Station, Hebei Normal University, Shijiazhuang, China, [2]School of Physical Education, Hebei Normal University, Shijiazhuang, China, [3]Key Laboratory of Measurement and Evaluation in Exercise Bioinformation of Hebei Province, Shijiazhuang, China

Objective: Mind wandering (MW) among athletes during training and competition can lead to poor performance. However, MW has also been found to have positive effects. This study aims to clarify the causes of the bidirectional (negative and positive) effects of MW in the sports context, specifically focusing on whether these effects are related to the content of MW.

Methods: A total of 846 Chinese athletes completed the Chinese version of the MW scales. The survey data were tested for common method biases. Subsequently, Pearson correlation analysis and structural equation modeling were performed using SPSS 25.0 and Mplus 7.0.

Results: The frequency of MW can positively predict its bidirectional effects. MW content plays an important role in the relationships between MW frequency and its negative and positive effects, but the direction of influence varies depending on the content.

Conclusion: MW in sports is not always harmful, and its content plays an important role. These findings suggest that managing MW content may be a promising MW intervention method for improving performance in sports.

KEYWORDS

athlete, content, frequency, mind wandering, performance

Introduction

Mind wandering (MW) refers to an experience in which the mind shifts away from the present task to unrelated inner thoughts (Smallwood and Schooler, 2006). It is a common phenomenon among human beings, accounting for 30–50% of people's waking hours (Kane et al., 2007). For athletes, the term MW refers to the mind not being tied to sporting tasks but instead focused on internal thoughts. Athletes often experience MW while on the train or in competitions. For example, tennis player Roger Federer said, "In a match, my mind wanders at times, sometimes a song comes to my mind, sometimes you are thinking about what's going to happen tomorrow, what you're going to do tonight, you might think about anything" (Netease Sports News, 2011).[1] In another example, during the Tokyo 2020 Olympics, Ukraine's Serhiy Kulish shot his rifle into another competitor's target. After the match, he recalled that his clothes felt slightly uncomfortable during the final moments of the match, causing his mind to wander (Sohu, 2021).[2] The characteristics of MW are multidimensional, including whether it is voluntary (Seli et al., 2015, 2016), temporal directionality (Smallwood et al., 2009), or meta-awareness (Smallwood et al., 2008). There are many theories explaining how and why MW occurs. Among them, the

1 http://sports.163.com/11/0224/09/6TL9TB7T00051CDG.html

2 https://www.sohu.com/a/497762179121048740

"decoupling hypothesis" explained in terms of cognitive resource allocation suggests that MW arises due to the coupling of attention to internal processing while decoupling it from task-relevant information (Smallwood and Schooler, 2006; Smallwood, 2010). Based on the "decoupling hypothesis," the athlete experiencing MW consumes cognitive resources.

However, the effect of MW is not homogeneous. MW has negative and positive effects (Mooneyham and Schooler, 2013; Torres-Irribarra et al., 2019; Salavera and Usán, 2020). Regarding the negative effects, MW can lead to dangerous driving behavior (Burdett et al., 2016; Albert et al., 2018) and cause nautical observers to miss critical radar signals (David et al., 2015). The sports field is no exception. MW has been confirmed to be very common among athletes during sporting events (Miś and Kowalczyk, 2021), and it can produce a series of negative effects, such as detrimental distraction (Latinjak, 2018), motor errors, energy consumption, emotional fluctuation, injuries, decreased training effectiveness, and poor competitive performance (Li and Yao, 2016). Regarding the positive effects, MW can anticipate and plan personal future goals (Baird et al., 2011). MW is also related to creativity, patience, cognitive control (Smallwood and Andrews-Hanna, 2013), and new solutions to old problems (Baird et al., 2012). Unexpectedly, the positive effect of MW has also been observed in the field of sports. For example, MW was found to be related to helpful distraction and sudden insight (Latinjak, 2018). MW during training for long-distance running enhances an individual's mood (Miś and Kowalczyk, 2021). Interviews with athletes have also revealed that MW is not always harmful; it also exhibits beneficial functions, such as improving one's mood and reducing fatigue (Li and Yao, 2016). Although the study of MW in sports is still in its infancy, the coexistence of its advantages and disadvantages has been demonstrated in the above studies. Therefore, instead of blindly asking athletes to reduce MW, the reason behind its bidirectional (negative and positive) effects should be clarified first.

To date, however, the reason for the bidirectional effects of MW remains unclear. Thought content profiles frequently vary considerably among individuals, and thus, the heterogeneity of MW must be considered. Therefore, it is necessary to consider the content characteristics of MW. Smallwood and Andrews-Hanna (2013) proposed the "content regulation hypothesis," which suggests that the effects of MW are likely to originate from their different contents. Repetitive thinking of negative and self-related content and excessive focus on memories and future thoughts are associated with negative emotions. However, adaptive, constructive, and highly self-relevant MW contents provide a means to address current concerns and facilitate insightful and creative problem-solving (Smallwood and Andrews-Hanna, 2013). Intra-individual analyses indicated that negatively valenced MW and MW without awareness correlated with worse performance (Welhaf et al., 2024). The "content regulation hypothesis" also states that MW content is time-oriented, and different time orientations (e.g., past and future) will have varying effects. Research has shown that future-pointing MW allows individuals to envision and plan for the future, which is closely related to personal goals.

In contrast, past-pointing MW is associated with negativity and low wellbeing; past-pointing wandering tends to be associated with negative emotions, while future-pointing MW is related to positive emotions (Smallwood and Andrews-Hanna, 2013). In the sports domain, Miś and Kowalczyk study (2021) concluded that future-pointing MW appears to promote positive mood shifts during runners' training. Thus, the content of MW largely determines its effect.

The "context regulation hypothesis," another theory proposed to analyze the effect of MW, argues that explaining the effect of MW also requires focusing on the task context (Smallwood and Andrews-Hanna, 2013). The training ground and the competition terrain where athletes are located differ from daily life situations. Thus, we should explore MW content corresponding to reality in sports situations. In addition, the "current concerns hypothesis" specifies that an individual's MW content is related to his/her personal goals or unaccomplished tasks (Klinger and Cox, 1987). Therefore, by combining the perspectives of the "content regulation hypothesis," "context regulation hypothesis," and "current concerns hypothesis," the effect of MW on athletes must consider its content features and combine the sports context with the current concerns of athletes.

Previous studies have categorized the content of MW considering the characteristics of the sports context and the current concerns of the athlete (Li and Yao, 2016). On this basis, the present study considers the content of athletes' MW and uses structural equation models to explore the bidirectional (negative and positive) effects of MW on training and competition contexts and whether different MW contents play a mediating role. The theoretical path model is shown in Figure 1, and the following hypotheses are proposed: (1) The frequency of athletes' MW can directly predict its positive and negative effects. (2) Different MW contents play different roles in the frequency of MW and negative effects. (3) Different MW contents play different roles in the frequency of MW and positive effects. The results of this study will provide scientific guidance for reducing the negative effect of MW on sports performance and guiding it toward a positive effect.

Materials and methods

Participants

The present study was approved by the relevant Ethics Committee (2023LLSC031), and all the subjects who participated in the survey provided informed consent. The participants were from professional sports teams and competitive sports schools in eight cities in China, namely Beijing, Tianjin, Shanghai, Chongqing, Xi'an, Chengdu, Zhengzhou, and Wenzhou. They had to train for more than 10 h a week and had to participate in competitions at or above the provincial level. Questionnaires were distributed online (web-based and password-protected) and on paper. Data were collected from 1,186 participants, and 340 were excluded by setting two polygraph questions and checking for regular responses, achieving an effective recovery rate of 71.332%. The final sample was 846 Chinese athletes. Among them, there were 570 men and 276 women: 357 athletes in the physique-dominated event group and 489 athletes in the skill-dominated event group; 379 athletes at level 2 or above; and 467 athletes below level 2. The average

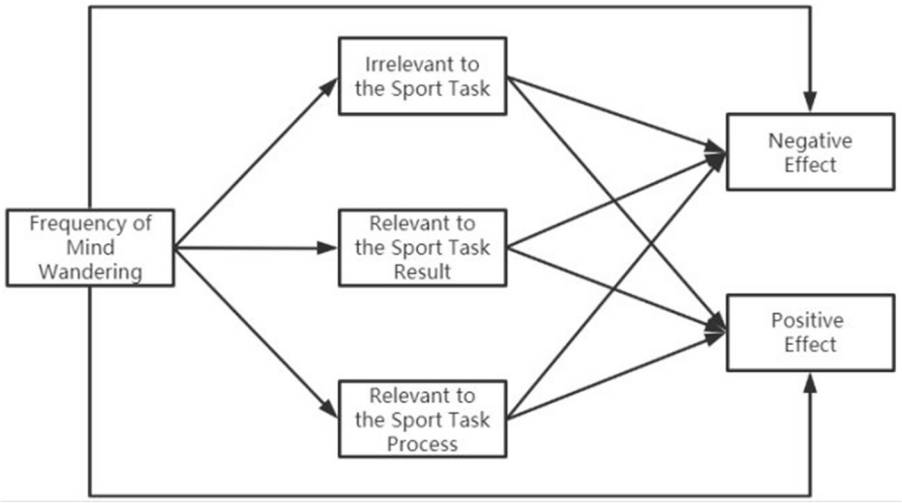

FIGURE 1
Hypothesis model.

age of the participants was 20.450 years ($SD = 2.407$). They had participated with their respective teams for an average of 5.880 years ($SD = 3.815$).

Measures

A series of scales developed in a previous study (Li and Yao, 2017) on athletes' MW was selected. The participants responded using a 5-point Likert-type scale from 1 (*never*) to 5 (*always*).

Frequency of MW

The frequency of MW among the athletes was measured using the *MW Cause Scale*. This scale investigates which situations make athletes more prone to MW during training and competition. Consequently, the total score measures how frequently MW occurs among athletes. This scale contains five dimensions: weak attentional control (three items; e.g., "When motor difficulty is low, my mind will wander"), spontaneous thinking (six items; e.g., "Near the end of training, my mind cannot help but wonder"), psychological gap (three items; e.g., "I zone out when the organization of the event changes suddenly"), competition mood (four items; e.g., "My mind will wander when I get too nervous"), and somatic sensation (five items; e.g., "My mind wanders when I am tired"), for a total of 21 items. To meet the model fit criteria, one item from the spontaneous thinking dimension was removed, leaving a total of 20 items. The internal consistency reliability for each dimension was 0.661, 0.806, 0.710, 0.800, and 0.826. The scale had good construct validity ($\chi^2/df = 2.968$, TLI = 0.911, AGFI = 0.894, CFI = 0.924, RMSEA = 0.059; Li and Yao, 2017).

Content of MW

The different MW contents of the athletes were measured using the *MW content Scale*. This scale is used to investigate the three different types of MW content during training and competition situations: irrelevant to the sports task (three items; e.g., "Remember something delicious that you have eaten before"), relevant to the sports task result (three items; e.g., "Remember the honor of victory"), and relevant to the sports task process (three items; e.g., "The change in the field is the change in the content of my wandering mind"), for a total of nine items. The internal consistency reliability for each dimension was 0.731, 0.756, and 0.723. The scale had good construct validity ($\chi^2/df = 2.968$, TLI = 0.957, AGFI = 0.948, CFI = 0.972, RMSEA = 0.059; Li and Yao, 2017).

Effect of MW

The bidirectional effects of the athletes' MW were measured using the *MW Result Scale*, which investigates the effect of MW during training and competition situations. It includes two dimensions: negative effect (seven items; e.g., "My competition scores will go down") and positive effect (five items; e.g., "Relieve tension during the game"). Negative effects include motor errors, energy consumption, emotional fluctuation, injuries, decreased training effectiveness, and competition performance. Positive effects include decision-making and emotional regulation. The negative dimension has seven items, while the positive dimension has five items, for a total of 12 items. To meet the model fit criteria, two items from the negative dimension and one item from the positive dimension were eliminated, leaving a total of nine items. The internal consistency reliability for each dimension was 0.820 and 0.844. The scale had good construct validity ($\chi^2/df = 2.969$, TLI = 0.941, AGFI = 0.933, CFI = 0.953, and RMSEA = 0.059; Li and Yao, 2017).

Data analysis

We computed means, standard deviations, and correlations for all the variables by using SPSS 22.0. Confirmatory factor analysis (CFA) was conducted using Mplus 7.0 to examine the

reliability, convergent validity, model fit, and multiple mediating effects. Among these, the test for multiple mediating effects yielded comparative mediating effects, allowing the researchers to determine which multiple mediating variables exerted a stronger effect. This study used the bootstrap method for multiple mediating effect analysis. This method involves the process of taking a large bootstrap sample (sample size = 1,000 for this study) and obtaining statistics through repeated sampling with put-backs. This method does not require normality assumptions or large samples, and it is useful for small to medium-sample analyses. Bootstrap methods include the percentile bootstrap method and the bias-corrected percentile bootstrap method. Both are presented in the reporting of the results of this study. When the confidence interval does not contain 0, then the indirect effect is significant.

Results

Common method bias test

To verify whether the survey has a significant systematic error, the Harman one-way method was used to test the common method bias of factors (Podsakoff et al., 2003). The analysis results showed that seven factors out of 42 had a characteristic root >1, and the percentage of the first factor explainable was 32.576%, which was lower than 40%, indicating no significant common method bias for the factors used in this study.

Reliability and validity tests of the scale

As shown in Table 1, compositional reliability and convergent validity were calculated to test the reliability of the questions and the ability of the dimensions to explain the questions. The component reliability of each dimension was close to or above 0.7. AVE refers to the average explanatory ability to determine the dimensions of an item. All the dimensions were >0.36, indicating that they were within an acceptable range. To test discriminant validity among the dimensions, this study calculated the correlation coefficients between each dimension and the correlation coefficients between each dimension and its sub-scale for comparison. The correlation coefficients between each dimension and its sub-scale were higher than those between other dimensions, representing good discriminant validity among all the dimensions.

Correlation among MW frequency, content, and bidirectional effects

The correlation analysis showed significant positive correlations among MW frequency, content, and positive and negative effects, as presented in Table 2.

In addition, the age of the athletes exhibited significant positive correlations with FMW, RSTR, and RSTP. The years of training of the athletes presented significant correlations with all the variables except for RSTR and NE. Therefore, the age and years of training of the athletes were analyzed as control variables in the subsequent analysis.

Testing the mediating model of different MW contents

On the basis of the correlation analysis, the mediating role of different MW contents in MW frequency and its negative and positive effects was further examined by constructing structural equation models. We generally used the target coefficient (TC) to determine whether the second-order CFA can replace the first-order CFA. The calculation formula is as follows: TC = first-order CFA fully correlated χ^2/second-order CFA χ^2. The closer TC is to 1, the more the second-order model can represent the first-order model appropriately, and reaching 0.74 is generally considered acceptable (Doll et al., 1994). In the present study, the frequency of MW was measured as a second-order model, TC = 649.641/687.438 = 0.945, which reached a criterion of 0.74, indicating that the second-order CFA model of the athletes' MW frequency can replace the first-order CFA model.

First, a structural equation model was constructed to examine the direct influence of MW frequency on the negative effect. The goodness-of-fit was acceptable, with indices of χ^2/df = 3.140, root-mean-square error of approximation (RMSEA) = 0.050, standardized root-mean-square residual (SRMR) = 0.040, comparative fit index (CFI) = 0.925, and Tucker–Lewis index (TLI) = 0.916. Among them, the recommended value of model fit, χ^2/df, is as small as possible, which is within 5 in accordance with the wider standard identified by Schumacker and Lomax (2004). The results showed that the direct influence of MW frequency on the negative effect was significant ($\beta = 0.674$, $p < 0.001$). Then, the direct influence of MW frequency on the positive effect was examined. Similarly, the goodness-of-fit was acceptable, with indices of $\chi^2/df = 3.172$, RMSEA = 0.051, SRMR = 0.042, CFI = 0.922, and TLI = 0.914. The results indicated that the direct influence of MW frequency on the positive effect was significant ($\beta = 0.60$, $p < 0.001$).

Then, a mediation test was conducted for negative effects. The goodness-of-fit was acceptable, with indices of $\chi^2/df = 2.794$, RMSEA = 0.046, SRMR = 0.044, CFI = 0.911, and TLI = 0.903. The results are presented in Figure 2, where the direct influence of the frequency of athletes' MW on the negative effect was significant ($\beta = 0.849$, $p < 0.001$). That is, the frequency of MW still positively predicted its negative effect. The frequency of athletes' MW exerted a significant predictive effect on MW contents that were irrelevant to the sports task ($\beta = 0.740$, $p < 0.001$), relevant to the sports task result ($\beta = 0.683$, $p < 0.001$), and relevant to the sports task process ($\beta = 0.878$, $p < 0.001$). MW contents that were irrelevant to the sports task ($\beta = -0.276$, $p < 0.01$) and relevant to the sports task result ($\beta = 0.141$, $p < 0.05$) were significant predictors of MW negative effect.

Lastly, a mediation test was conducted for positive effects. The goodness-of-fit index was acceptable, with $\chi^2/df = 2.789$, RMSEA = 0.046, SRMR = 0.042, CFI = 0.913, and TLI = 0.905. The results are presented in Figure 3, where the direct influence of the frequency of athletes' MW on positive effect was insignificant (β

TABLE 1 Reliability and validity.

Dimension	WAC	ST	PG	CM	SS	IST	RSTR	RSTP	NE	PE
WAC	**0.735**									
ST	0.610	**0.872**								
PG	0.513	0.589	**0.767**							
CM	0.469	0.611	0.587	**0.818**						
SS	0.527	0.666	0.568	0.634	**0.862**					
IST	0.380	0.541	0.454	0.436	0.418	**0.808**				
RSTR	0.534	0.643	0.546	0.741	0.721	0.418	**0.839**			
RSTP	0.509	0.589	0.570	0.553	0.552	0.588	0.542	**0.846**		
NE	0.415	0.453	0.393	0.392	0.479	0.270	0.399	0.404	**0.881**	
PE	0.408	0.511	0.478	0.487	0.446	0.532	0.453	0.586	0.334	**0.741**
CR	0.680	0.793	0.725	0.803	0.834	0.733	0.782	0.740	0.839	0.788
AVE	0.416	0.434	0.468	0.506	0.503	0.480	0.545	0.489	0.511	0.483

The diagonal bold is the Pearson correlation between dimensions and the sub-scale to which they belong, and the lower triangle is the Pearson correlation between dimensions.
WAC, Weak Attentional Control; ST, Spontaneous Thinking; PG, Psychological Gap; CM, Competition Mood; SS, Somatic Sensation; IST, Irrelevant to the Sports Task; RSTR, Relevant to the Sports Task Result; RSTP, Relevant to the Sports Task Process; NE, Negative Effect; PE, Positive Effect.

TABLE 2 Descriptive statistics and correlation analysis results of frequency, content, and bidirectional effects of MW.

Variable	M ± SD	1	2	3	4	5	6	7	8	9
1. FMW	45.025 ± 12.248	1								
2. IST	5.717 ± 2.202	0.549**	1							
3. RSTR	6.83 ± 2.157	0.502**	0.487**	1						
4. RSTP	6.522 ± 2.412	0.678**	0.588**	0.539**	1					
5. NE	13.909 ± 4.217	0.526**	0.270**	0.374**	0.404**	1				
6. PE	8.805 ± 2.974	0.571**	0.532**	0.406**	0.586**	0.334**	1			
7. Gender	–	0.065	−0.003	−0.051	0.059	0.016	0.008	1		
8. Age	20.45 ± 2.407	0.095**	0.058	0.118*	0.108**	0.048	0.052	0.055	1	
9. YT	5.88 ± 3.815	−0.095**	−0.108**	−0.043	−0.086*	0.015	−0.140**	0.058	0.302**	1

*$p < 0.05$.
**$p < 0.01$.
FMW, Frequency of Mind Wandering; IST, Irrelevant to the Sports Task; RSTR, Relevant to the Sports Task Result; RSTP, Relevant to the Sports Task Process; NE, Negative Effect; PE, Positive Effect; YT, Years of Training.

= 0.035, $p = 0.821$). The frequency of athletes' MW significantly predicted the MW contents that were irrelevant to the sports task ($\beta = 0.738$, $p < 0.001$), relevant to the sports task result ($\beta = 0.684$, $p < 0.001$), and relevant to the sports task process ($\beta = 0.880$, $p < 0.001$). MW contents that were irrelevant to the sports task ($\beta = 0.318$, $p < 0.001$) and relevant to the sports task process ($\beta = 0.496$, $p < 0.01$) were significant predictors of MW positive effect.

Indirect effect path test

The results of the mediating effect were analyzed by examining the three different MW contents and comparing the results of the three mediating effects. First, the multiple mediators of negative effect were examined, as indicated in Table 3. The frequency of athletes' MW exerted a significant indirect influence on negative effects through MW contents that were irrelevant to the sports task [$\beta = -0.342$, BC 95% confidence interval [CI] = [−0.627, −0.145], percentile 95% CI = [−0.637, −0.149]] and relevant to the sports task result [$\beta = 0.162$, BC 95% CI = [0.012, 0.325], percentile 95% CI = [0.022, 0.346]]. Further comparison of the mediating effects revealed that the negative effect from MW contents that were irrelevant to the sports task was significantly smaller than that from MW contents that were relevant to the sports task results [$\beta = -0.504$, BC 95% CI = (−0.817, −0.22), percentile 95% CI = (−0.871, −0.266)].

Then, the multiple mediators of positive effect were tested for three different MW contents. The results of the comparative analysis of the three mediating effects are provided in Table 4. The results indicated that the MW frequency of the athletes exerted a significant indirect influence on positive effect through MW contents that were irrelevant to the sports task [$\beta = 0.341$, BC 95% CI = [0.198, 0.536], percentile 95% CI = [0.198, 0.538]] and

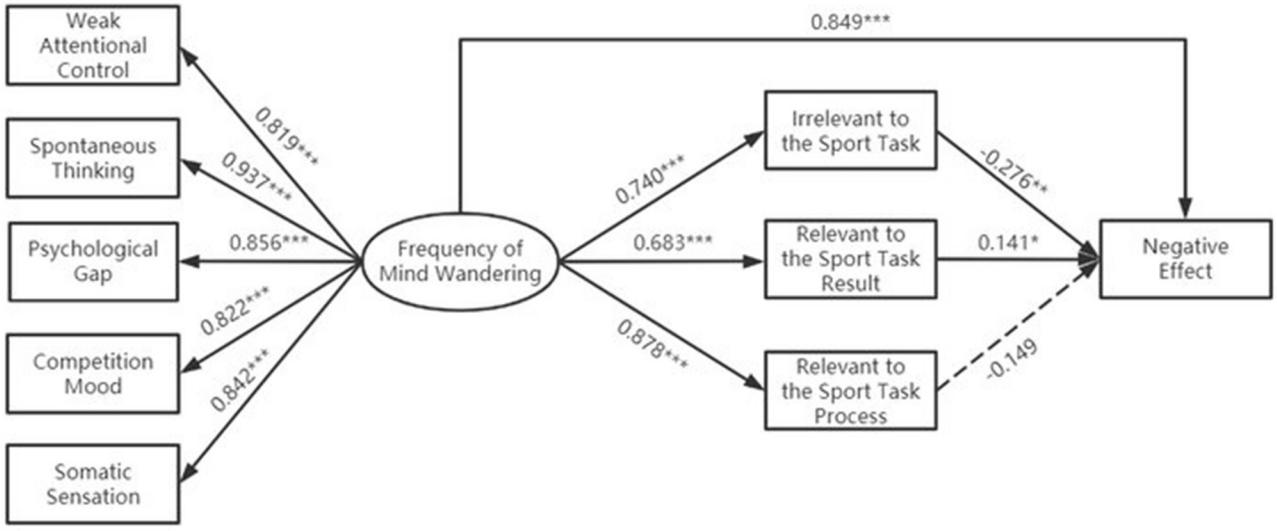

FIGURE 2
Relationship between the frequency of mind wandering, content of mind wandering, and its negative affect.

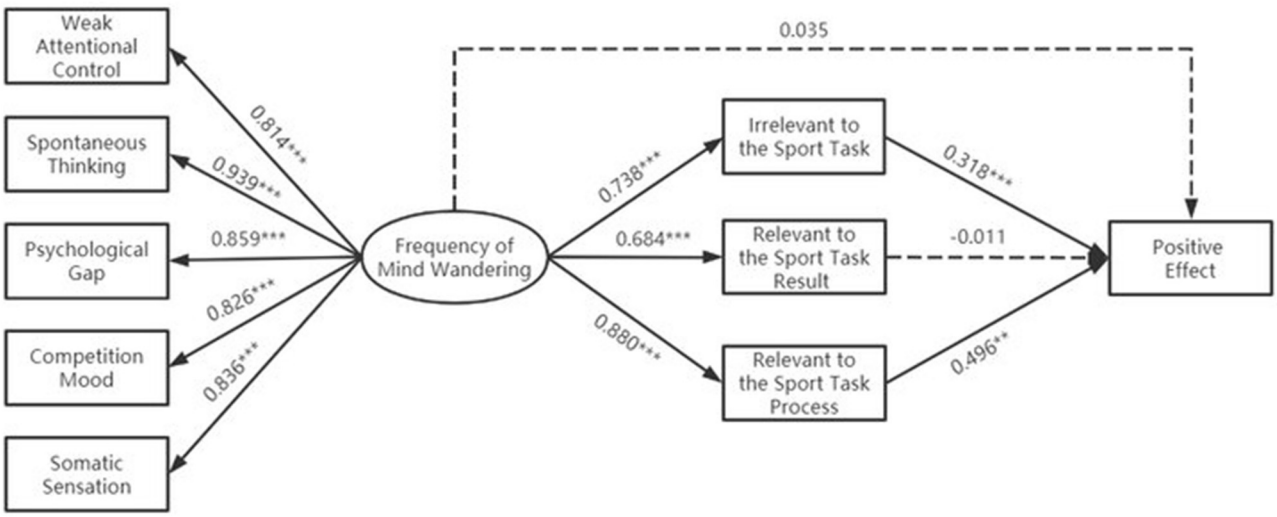

FIGURE 3
Relationship between the frequency of mind wandering, content of mind wandering, and its positive affect.

relevant to the sports task process [$\beta = 0.635$, BC 95% CI = [0.274, 1.093], percentile 95% CI = [0.289, 1.148]]. Further comparison of the results of the mediating effect showed that the positive effect from MW contents that were irrelevant to the sports task was not significantly different from that of the MW contents that were relevant to the sports task process.

Discussion

The present study examined the bidirectional effects of the frequency of athletes' MW and the role of different MW contents through multiple mediation model testing. The frequency of athletes' MW not only directly predicted negative and positive effects but also indirectly predicted negative and positive effects through different MW contents.

The occurrence of MW in athletes may have bidirectional effects

The occurrence of MW may have a bidirectional effect in training and competition situations through retrospective surveys. First, this study showed that the frequency of MW among athletes positively predicted the negative effect, supporting Hypothesis 1. The result of this study is consistent with previous studies. One study concluded that MW happens when athletes perform sports

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TABLE 3 Comparative analysis of specific indirect effect (negative).

	Point estimate	Product of coefficient			Bootstrap 1,000 times 95% CI			
					Bias corrected		Percentile	
		S.E.	Est./S.E.	*P*-value	Lower	Upper	Lower	Upper
Indirect effect								
IST	−0.342	0.120	−2.854	0.004	−0.627	−0.145	−0.637	−0.149
RSTR	0.162	0.085	1.918	0.055	0.012	0.325	0.022	0.346
RSTP	−0.220	0.234	−0.940	0.347	−0.734	0.164	−0.728	0.178
Total	1.026	0.095	10.848	0.000	0.843	1.215	0.854	1.233
Contrasts								
IST vs. RSTR	−0.504	0.150	−3.363	0.001	−0.817	−0.22	−0.871	−0.266
IST vs. RSTP	−0.122	0.268	−0.456	0.649	−0.616	0.423	−0.627	0.388
RSTR vs. RSTP	0.382	0.259	1.475	0.140	−0.084	0.912	−0.058	0.937

IST, Irrelevant to the Sports Task; RSTR, Relevant to the Sports Task Result; RSTP, Relevant to the Sports Task Process.

TABLE 4 Comparative analysis of specific indirect effect (positive).

	Point estimate	Product of coefficient			Bootstrap 1,000 times 95% CI			
					Bias corrected		Percentile	
		S.E.	Est./S.E.	*P*-value	Lower	Upper	Lower	Upper
Indirect effect								
IST	0.341	0.086	3.952	0.000	0.198	0.536	0.198	0.538
RSTR	−0.011	0.064	−0.175	0.861	−0.119	0.136	−0.130	0.127
RSTP	0.635	0.219	2.901	0.004	0.274	1.093	0.289	1.148
Total	1.016	0.094	10.812	0.000	0.852	1.213	0.855	1.226
Contrast								
IST vs. RSTR	0.352	0.116	3.049	0.002	0.133	0.608	0.130	0.598
IST vs. RSTP	−0.294	0.226	−1.301	0.193	−0.773	0.107	−0.802	0.103
RSTR VS. RSTP	−0.646	0.242	−2.671	0.008	−1.193	−0.215	−1.201	−0.243

IST, Irrelevant to the Sports Task; RSTR, Relevant to the Sports Task Result; RSTP, Relevant to the Sports Task Process.

tasks during training and competition, which leads to negative effects (Latinjak, 2018). Therefore, it is clear that the negative effect of MW on athletes cannot be ignored.

The negative effect of MW on athletes can be interpreted by combining the "decoupling hypothesis" and the "context regulation hypothesis." The decoupling hypothesis suggests that MW occurs because attention is coupled with internal processing while being decoupled from task-related information (Smallwood et al., 2003; Smallwood and Schooler, 2006; Smallwood, 2010). Athlete's attention is required to focus on tasks, whether in training or competition situations. On the basis of this theory, MW occurs when an athlete's attention is coupled with his/her own internal thoughts and disengaged from the current sports task, resulting in a negative effect on the athlete. Moreover, in accordance with the "context regulation hypothesis," the task context should be considered when evaluating the effect of MW (Smallwood and Andrews-Hanna, 2013). Individuals who experience MW during sustained attention tasks can exhibit impaired performance (Gouraud et al., 2018). Similarly, the occurrence of MW is detrimental in the context of a sustained attention task, such as training and competition situations, wherein athletes frequently need to process multiple pieces of information. One study also found that MW exerted a negative effect on fine motor movement control, supporting the idea that a decoupling of sensory-motor processes occurs during MW (Dias Da Silva and Postma, 2022).

The present study also showed that MW frequency in athletes positively predicted a positive effect, supporting Hypothesis 1. The result of this study is consistent with previous studies. MW in athletes has positive effects, such as fatigue reduction and mood improvement (Latinjak, 2018). In addition, previous studies have found that MW has positive effects on problem-solving and enhancing individual creativity (Preiss, 2022; Teng and Lien, 2022; Yang and Wu, 2022). MW can be viewed from a switching perspective (Wong et al., 2023). MW among athletes is the switch between two states (from focusing on oneself to the task of the sports) that can facilitate their creative thinking and decision-making, i.e., producing positive effects. Meanwhile, studies have shown that increasing perceptual load may impair,

rather than improve, sports performance. Increased task demands can be counterproductive and even extremely dangerous in some situations (Aitken et al., 2023). Sustained cognitive tasks in the sports context will gradually increase an athlete's cognitive load and may exert an opposite effect if the athlete is required to focus on the sports task all the time. In addition, focusing on something other than running itself will improve, rather than impair, running economy during running exercise (Schücker et al., 2009). The "opportunity cost model" (Kurzban et al., 2013) is an important perspective that proposes a role for MW in the experience of boredom and the negative effect that often occurs during ongoing task performance. The model assumes that when the opportunity cost of a low-reward task is too high, our brains have an inherent tendency to seek rewards and stimulation elsewhere. This tendency drives us to engage in other mental tasks that may contribute to greater subjective rewards, including MW. The growing opportunity cost manifests itself in distasteful subjective mental states, including boredom, effort, stress, and fatigue. However, athletes are often in these objectionable subjective mental states during training and competition. At this point, MW plays a positive role in the experience of boredom and negative effects that commonly occur during training and competition. Therefore, MW is not detrimental in all sports situations; that is, MW during training and competition can also have positive effects.

In conclusion, athletes believe that MW can have both positive and negative effects on them. "MW in sporting performance (MWSP)" is a theory of MW that has been proposed specifically in the sports context. MWSP explored the reason for these bidirectional effects. MWSP considers that MW occupies limited attentional resources. The amount of attentional resources occupied by MW varies by its different content, resulting in different attentional resources left for sports tasks; When the attentional resources for sports tasks are reduced, the resources are not able to sustain the task during the competition, and performance will decrease (or vice versa; Li et al., 2024). The "decoupling hypothesis" emphasizes that MW takes up attentional resources, and MWSP builds on this by further suggesting that there are differences in the attentional resources taken up by MW due to its different contents, which ultimately leads to the fact that MW will have different effects on athletes. The present study suggests that we should give considerable attention to the serious negative effect of MW, which may lead to mistakes and missed medals for athletes during competition. Simultaneously, we should not blindly intervene in the occurrence of MW to avoid hiding its positive effect.

The role of different MW contents

Based on data from the athlete's self-report, the indirect effect test revealed that three different MW contents played different roles in the frequency of MW and its negative effects. Specifically, the frequency of athletes' MW exerted a negative indirect influence on negative effects through MW contents that were irrelevant to the sports task. The frequency of athletes' MW positively influenced negative effects through MW contents that were relevant to the sports task result. Further comparison of the indirect effect results revealed that negative effects from MW contents that were irrelevant to the sports task were significantly smaller than those from MW contents that were relevant to the sports task result. Therefore, the indirect effects differ significantly, supporting Hypothesis 2.

MW contents relevant to the sports task result included rewards and honors, the final outcome of the competition, and the direct result of the motor (Li and Yao, 2016). The negative effect of MW contents that were relevant to the sports task result may be due to the fact that athletes recognize the importance of the competition and focus excessively on the rewards. However, it does not help athletes improve or maintain their performance; rather, it has the opposite effect. This type of additional attention is generally associated with the conscious control of the motor process, which can disrupt the automatic execution of the original action, leading to changes in movements that athletes are already accustomed to Belletier et al. (2015). Then, it produces a detrimental effect. In addition, the indirect effect of MW contents, which was irrelevant to the sports task, was significant but had a negative effect. MW contents that are irrelevant to the sports task included post-competition activities, life events, relatives, and friends (Li and Yao, 2016). Athletes may wonder about the expectations of their relatives and friends during training and competition. These expectations will be converted into motivation for athletes to improve their sports performance. Relevant evidence was provided by one study that motor learning benefits when expectations are enhanced (Simmonds et al., 2023). Therefore, MW contents that are irrelevant to the sports task may function as motivators for athletes, which explains the result that it is a negative predictor of negative affect in another way. Finally, the indirect effect of MW contents that were relevant to the sports task process was not significant. The reason for this result may be that the athlete's attention was not disengaged from the sports task while he or she was thinking about the content related to the sports task. The consistency of attention to the sports task protected it from the negative effects.

Meanwhile, based on athlete self-reported data, the present study found that three different MW contents play different roles in the frequency of MW and its positive effects. Specifically, the frequency of MW in athletes exerted a positive indirect influence on positive effects through MW contents that were irrelevant to the sports task and relevant to the sports task process. Further comparison of the indirect effects showed that the differences were insignificant, partially supporting Hypothesis 3. MW frequency in athletes had a positive effect through MW content that was irrelevant to the sports task. This result may be due to the training and competition contexts being continuous cognitive and physical activities under high pressure, gradually depleting the cognitive resources and physical exertion of athletes over time and causing them to feel fatigued. The occurrence of MW allows athletes to temporarily disconnect from their stressful environment and let their minds rest and relax appropriately to relieve fatigue. This situation is similar to the previous finding in which MW appears to promote a positive mood during a runner's training (Miś and Kowalczyk, 2021). In addition, we found an indirect positive effect of MW content that is relevant to the sports task process. This

type of MW content will change with the course of a game and includes the next segment of the competition, contextual change, opponent-related, and action-related (Li and Yao, 2016). On the basis of the "current concerns hypothesis," an individual's MW content is associated with personal goals or uncompleted tasks, and it will facilitate anticipation and planning for future goals. This result is similar to previous research findings, in which MW can lead to problem-solving and planning for personal, relevant future goals. The prospective nature of MW may be functional; that is, future-oriented MW allows people to plan and think about their future goals (Mooneyham and Schooler, 2013). In the sports context, information related to the sports task process constitutes the current focus of athletes. To win the game, athletes may plan and organize the entire sports process. The content of these thoughts is also part of the athlete's personal relevant goals. The occurrence of MW in athletes is the process of approaching personal goals, which is beneficial for athletes' performance in the sports process and, thus, exerts a positive effect. However, we did not find a significant indirect effect of MW contents relevant to the task of the sports, resulting in a positive effect. As discussed above, excessive focus on the result by athletes can lead to increased stress, disruption of the original, inherent automatic procedures of movements, and consequently, the production of negative effects, such as motor errors. Therefore, coaches and athletes can use MW content and try to guide the positive effect it brings to training and competition. These results are in accordance with the results of the above negative model, and they also validate the accuracy of the present study.

In summary, athletes believe that the impact of MW will vary depending on its content. The findings suggest that the different contents of MW need to be taken into account when studying the effects of MW on athletes in future research. Through athletes' self-reports, the current study not only analyzed the relationship between different MW contents and negative effects but also the relationship with positive effects. The present study shows that the results in the two opposite directions are not contradictory and serve to validate each other. Our survey results support the "content regulation hypothesis" that MW exerts different effects depending on the content features. It is worthwhile to recognize that this questionnaire-based study was conducted with athletes in training and competition situations. The findings enrich the research on the effects of MW in different contexts. The findings suggest that coaches attempt to guide the thinking habits of athletes in sports practice. In particular, less attention should be given to the results and more to the process. Allowing athletes to think about content unrelated to the sports task at the interval of the competition and training can play a positive role in relieving mood and fatigue. Hence, athletes believe that not all MW is harmful, and blindly reducing MW is unscientific. Before measuring its pros and cons, we must consider the specific content features of MW.

Limitations and future directions

However, this study has some limitations that require improvement in future studies. First, this study focused on MW and its effects in the competitive sports context without distinguishing in detail between training and competition. It also did not distinguish among the characteristics of different sports. To make the findings more targeted to guide practice, future research can refine the occurrence of the MW context (training or competition) in specific sports. Second, the present study classified the content of athletes' MW in relation to sports tasks. This classification is based on preliminary qualitative research, and all the factors have achieved satisfactory validity test results. Future research can select athletes from other countries and regions to verify the feasibility of this classification further. In addition, future researchers are encouraged to classify MW content from other perspectives, such as affective valence and time orientation. Third, athletes' MW in this study was collected through a retrospective questionnaire. Compared with the method of online probes for athletes' inner experience, a retrospective questionnaire is easy to operate and does not destroy the natural state of thinking. However, different methods have their merits and limitations, and a retrospective questionnaire is subjective and cannot verify causality between variables. Future research can consider different approaches, e.g., using online probes in a laboratory or a simulated competition context to collect data and enhance the reliability of the data analysis results. In particular, we suggest that future experimental studies can build on the results of the present study to further validate the causal relationship between different MW contents and athletic performance in sports.

Conclusion

Based on data from a questionnaire survey of athletes, this study used structural equation models to examine the bidirectional effects of MW in sports and the role of different MW contents. The frequency of MW can positively predict its bidirectional effects. MW content plays a multiple mediating role between them, but the direction of influence varies with different contents. The results highlight the importance of MW content. In particular, athletes' MW exerts the strongest negative effect through contents relevant to the sports task result. It has an equally positive effect through content that is irrelevant to the sports task and relevant to the sports task process. The results suggest that managing MW content is a promising intervention method. It has important theoretical and practical implications for improving sports performance.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Ethics Committee: Heibei Normal University; No. 2023LLSC031. 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

JL: Conceptualization, Funding acquisition, Project administration, Supervision, Writing – original draft. CL: Methodology, Writing – review & editing. SX: Data curation, Writing – review & editing. YH: Conceptualization, Supervision, Writing – original draft.

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Conflict of interest

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

Publisher's note

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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Mário Cunha Espada,
Instituto Politecnico de Setubal (IPS), Portugal
Khadijeh Irandoust,
Imam Khomeini International University, Iran

*CORRESPONDENCE
Yuhong Wen
✉ wyhswim@126.com

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The influence of competitive anxiety of Chinese elite swimmers

Yuhang Zhou[1,2], Zhenyu Jin[2,3] and Yuhong Wen[1,2]*

[1]School of Recreational Sports and Tourism, Beijing Sport University, Beijing, China, [2]Key Laboratory of Sport Training of General Administration of Sport of China, Beijing Sport University, Beijing, China, [3]China Swimming College, Beijing Sport University, Beijing, China

Background: Competitive anxiety is a common stress response in competitive environments, influencing sports performance, particularly among elite swimmers.

Purpose: This study aims to examine how the characteristics of competitive anxiety impact sports performance across different phases of competitive preparation, alongside its correlation with trait anxiety.

Methods: A longitudinal research design, integrating quantitative and qualitative approaches, was employed with 20 swimmers from the Chinese national swimming team participating in both the 2023 Fukuoka World Championships and the Hangzhou Asian Games. The mental readiness form-3 (MRF-3) scale was employed at four time points during the preparation period for longitudinal tracking, complemented by the trait anxiety inventory (T-AI) scale to assess trait anxiety.

Results: The study identified a negative correlation between cognitive anxiety and somatic anxiety among elite swimmers, with confidence demonstrating a positive correlation. Additionally, there was a significant between trait anxiety and competitive anxiety ($p < 0.05$). Variations in competitive anxiety were found at different stages of the preparation cycle ($F = 15.074$; 11.627; 19.552, $p < 0.05$), impacting sport performance.

Conclusion: To optimise performance, tailored psychological intervention programs should be developed and implemented to address the distinct characteristics of competitive anxiety experienced by elite swimmers throughout the preparation phases.

KEYWORDS

competitive anxiety, trait anxiety, elite athletes, swimming, sport

1 Introduction

Swimming, a cornerstone of China's competitive sports strategy, is a crucial event in the Olympic Games and one of the most competitive sports (Chen, 2021). The 14th Five-Year Plan for Sports Development emphasises the need to vigorously promote foundational sports such as track and field and swimming (General Administration of Sport, 2021), with a focus on continually improving competitiveness. Research indicates that enhancing swimmers' competitiveness involves physical, psychological, and biomechanical factors (Amara et al., 2021a,b; Lopes et al., 2021). Swimming's prominence in the Olympics has led researchers to investigate the attributes that distinguish elite swimmers from the rest (Barbosa et al., 2010). For athletes, competition tests not only their athletic ability, but also their psychological

resilience. At the highest levels, competitive sport often becomes a context of psychological strength. Studies suggest that while technical and physical skills set the performance range of athletes, psychological factors significantly influence their competitive status and performance (Jones et al., 2018). Moreover, numerous studies have shown that competitive anxiety, a common psychological issue, can impact athletes' performance.

Anxiety is often defined as a negative psychological state experienced when completing a task under perceived pressure (Martens et al., 1990). It is characterised by tension and worry and is associated with physical activation or arousal (Nascimento et al., 2012). Spielberger categorized anxiety into two types: Trait anxiety, which is a relatively stable personality tendency, and state anxiety, which is a temporary, situation-specific condition (Spielberger, 1966).

According to Baumeister (1984), competitive anxiety is an athlete response to a stressful competitive situation. It involves a series of cognitive appraisals, behavioural responses, and physiological arousals to perceived stressors specific to the sport (Martens et al., 1990), which add to the general state anxiety. Competitive anxiety, one of the many emotions athletes may experience during competition, is a key constraint on performance. Initially, competitive anxiety was categorized into cognitive anxiety and somatic anxiety. Cognitive anxiety refers to the subjective worry about a threatening situation occurring immediately before, during, or after the competition, and stems from negative self-evaluations or performance expectations. Somatic anxiety is the emotional experience of the autonomic nervous system, caused directly by its arousal during the same periods. Martens et al. (1990) later added the dimension, self- confidence, which encompasses athletes' beliefs about their potential of success before, during, and after a competition.

Competitive anxiety affects sport performance. The multidimensional theory of anxiety proposed by Morris et al. (1981) explains this relationship, suggesting that sport performance is related to athletes' trait and state anxiety. Athletes with high levels of trait anxiety are likely to experience high levels of state anxiety during competition. A meta-analysis, which included 3,589 athletes across 77 sports, found that anxiety generally has a negative correlation with sport performance (Kleine, 1990). These findings align with those of Lee et al.'s (2020), who also noted the detrimental effect of anxiety on performance (Lee et al., 2020). Scholars have specifically suggested that anxiety affects swimming performance (Dalamitros et al., 2019; Clemente-Suárez et al., 2021). This study investigates the relationship between sport performance and competitive anxiety, using World Swimming Federation points to quantify sport performance. These points represent a swimmer's best mark relative to the world best mark (Morais et al., 2020).

Most current research on the effects of competitive anxiety analyses the links between competitive anxiety, athletes' demographic characteristics, and sporting situations (Lee et al., 2020). Some studies have found higher levels of competitive anxiety in females than in males (Amaro and Brandão, 2023), as evidenced by higher scores on cognitive and somatic anxiety and lower scores on self-confidence. However, no significant differences have been found between the sexes (Guillén and Álvarez-Malé, 2010). In some cases, men exhibit higher levels of anxiety than women in team sports such as football (Esteves et al., 2021). Sporting situations can significantly impact athletes' competitive anxiety. For example, the presence or absence of spectators can significantly impact young athletes' anxiety levels. Athletes with strong competition confidence often thrive on the attention of a large audience, using it as motivation to achieve excellence (Cai, 2015).

In addition to individual differences affecting levels of competitive anxiety, previous research has shown that training also impacts athletes' psychological states (Köroglu and Yigiter, 2016). As a result, scholars have begun monitoring the effects of training volume on psychological states (Freitas et al., 2014). The findings suggest that training cycles, which include changes in training load, correspond to specific emotional changes (Winsley and Matos, 2011). This indicates that training load directly influences the psychological state of the athlete. In high-level swimmers, anxiety states during the training period before major competition show a clear trajectory, characterised by either high intensity training (Morgan and Hayward, 1988) or sharply reduced training load (O'Connor et al., 1989). This is evidenced by high training loads correlating with highly competitive anxiety values (Chortane et al., 2022).

Some scholars have emphasised through meta-analysis that appropriate intervention for competitive anxiety can prolong athletes' sports life (Reynoso-Sánchez and Hoyos-Flores, 2023) and improve their career satisfaction (Rice et al., 2019). Excessive competitive anxiety can negatively affect athletes' training, pre-competition preparation, and performance. Therefore, it is essential to control athletes' competitive anxiety to optimise their performance (Pulido et al., 2021). Addressing and exploring the competitive anxiety of elite swimmers during critical preparation periods, and implementing effective interventions to improve their mental health, is a crucial issue for the development of competitive sports.

Most existing studies have explored athletes' competitive anxiety in relation to demographic variables such as gender but have not focused on elite swimmers at different points in time to accurately capture the characteristics of their competitive anxiety levels throughout the preparation cycle (Sanader et al., 2021). This approach is necessary to propose targeted optimisation measures. Therefore, tthe present study aims at analysing the demographic characteristics of elite swimmers' competitive anxiety during their preparations for the World Championships and the Asian Games, as well as to examine competitive anxiety at different points in time and its relationship with sport performance, aims to examine how the characteristics of competitive anxiety impact sports performance across different phases of competitive preparation, alongside its correlation with trait anxiety.

Based on the relevant literature, we hypothesised:

> *H1*: There are differences in the level of competitive anxiety among elite swimmers with different demographic characteristics;
>
> *H2*: Somatic and cognitive anxiety are significantly positively correlated and significantly negatively correlated with self-confidence;
>
> *H3*: Trait anxiety predicts competitive anxiety;
>
> *H4*: There are significant differences in the levels of competitive anxiety among elite swimmers at different time points;
>
> *H5*: Competitive anxiety influences sport performance.

2 Materials and methods

2.1 Methodological approach

Methodology is "the theory of the method of understanding and transforming the world" (Shao and Chen, 2002). In sport science research positivist methodology, characterised by a trend towards quantification, is increasingly dominant. Shao, Chen, and others emphasised the need to strengthen this quantitative approach to improve the overall level of sports and social sciences. This improvement should start with the accumulation of empirical evidence and then move towards theoretical development (Zhang, 2005). This is why the current paper relies on the questionnaire survey method. However, constructivists argue that facts are not external to our existence but are constructed through our interactions with the outside world and others. They see knowledge as something that is generated rather than discovered. The qualitative research paradigm emphasises that the formation and development of knowledge is not limited by inherent rational principles or purely rational inference (Zhang, 2002). Instead, knowledge is built by the conscious actions of individuals in their everyday interactions, a process of "negotiation." Given that the elite swimmers in this study are at the Olympic delegation level, there is considerable individual variation. Combining both quantitative and qualitative perspectives allows for a richer and more comprehensive study.

2.2 Subjects

The subjects of this study were 20 athletes from the Chinese National Swimming Team (subject information is shown in Table 1).

A priori power analysis (G * Power 3.1.9.6, Heinrich Heine Universität Düsseldorf, Düsseldorf, Germany) yielded a sample size of at least 12 swimmers in one time point to detect medium effects, assuming a power of 0.8 and alpha of 0.05. Thus, result of power analysis provided evidence that sample size of the present study is acceptable.

All the World Aquatics points were retrieved from publicly accessible database "swimrankings.net." The database lists are the results of registered races which are in accordance with the official World Aquatics rules (World Aquatics, 2023), including electronical time keeping and limits to in-pool current (Born et al., 2020). In this study, the 2023 World Aquatics points reference values were used.

The inclusion criteria for this study were: (1) age 15 years or older; (2) qualification for both the Fukuoka World Championships and the Hangzhou Asian Games in a single event; and (3) ability to complete the surveys at all time points in this study. A total of 30 swimmers from the Chinese swimming team met the first two criteria 1 and 2, but 10 were excluded because they could not complete the questionnaires at all required time points, thus not meeting the third criterion.

Elite athletes are those who compete at the professional and Olympic levels (Shi and Ma, 2022). The selection process of the Chinese delegation for the Fukuoka World Championships and Hangzhou Asian Games took place during the National Swimming Championships in May. The high caliber of swimmers selected for the two delegations aligns well with the elite characteristics of the swimmers in this study. These two events, being significant competitions preceding the Olympic Games preparatory cycle, are highly valued by all stakeholders.

All respondents signed the Informed Consent form, which was approved by the Sports Science Experiment Ethics Committee, study name "The influence of competitive anxiety of elite swimmers" (No. 2023261H).

2.3 Methods

2.3.1 Trait anxiety scale

The State–Trait Anxiety Inventory (STAI), developed and revised by Charles Spielberger, comprises two subscales: the State Anxiety Inventory (S-AI) and the Trait Anxiety Inventory (T-AI) (Spielberger, 1966). Only the Trait Anxiety Inventory (T-AI) was used in this study, consisting of 20 items. Items, including 11 positively scored items and 9 negatively scored items, rated on a four-point scale. Higher scores indicate higher levels of trait anxiety in individuals. $x^2/df = 3.90$, TLI = 0.92, CFI = 0.94, RMSEA = 0.05, SRMR = 0.05, Indicating good construct validity of the scale, the Cronbach a = 0.86. The scale was administered to all participants in a calm state of mind, without

TABLE 1 Demographic characteristics of all the participants.

Variable	Category	Frequency	Percentage	Percentage with WR
Gender	Male	10	50%	93.18%
	Female	10	50%	93.26%
Age	<19	5	25%	92.64%
	≥19and < 21	7	35%	93.89%
	≥21	8	40%	93%
Training years	<9	7	35%	93.97%
	≥9and < 13	7	35%	91.39%
	≥13	6	30%	94.48%
Sports grade	World-class	14	65%	95.53%
	National	6	35%	87.83%

"Percentage with WR" is refer to swimmers' World Aquatics Points percentage of the world record. The World Aquatics Points Table allows comparisons of results among different events. The World Aquatics Point Scoring assigns point values to swimming performances, more points for world class performances typically 1,000 or more and fewer points for slower performances.

TABLE 2 Interviewee information.

ID	Gender	Age	Training Years	Best performance
A1	Female	25	19	Olympic Champion
A2	Female	21	15	Olympic Champion
A3	Male	24	19	World Champion
A4	Female	19	12	World Champion
A5	Male	16	11	World Champion
A6	Male	20	13	Asian Games Champion

considering their training schedules. Validated factor analysis of the scale.

2.3.2 Competitive anxiety scale

The study participants' state anxiety was assessed using the Mental Readiness Form-3 (MRF-3) (Krane, 1994). The MRF-3 offers a less invasive and time-consuming alternative to longer questionnaires, making it suitable for situations requiring repeated measures and shorter completion times (Wilson et al., 2009; Beseler et al., 2016). It consists of three scales, each a two-ended continuum, ranging from 1 to 11. These scales assess cognitive anxiety (ranged from relaxed to worried), somatic anxiety (ranged from relaxed to tense), and assertiveness (ranged from confident to fearful). All participants completed the MRF-3 pre-test in a quiet setting, establishing the baseline value (T0). A random measure of competitive anxiety during a high-volume training session was recorded as T1. Anxiety levels were measured 30 min before the Fukuoka World Championships (T2); and 30 min before the Hangzhou Asian Games was recorded (T3).

2.3.3 Semi-structured interview

The interview method is commonly used in qualitative research to gather information from participants through questioning (Chen, 2006). For this study, a semi-structured interview approach was chosen. In semi-structured interviews, the interviewer asks questions based on a prepared outline but maintains flexibility in the interview's structure. The interviewer can adjust the order of questions according to the flow of the conversation and the respondents' answers. This method allows respondents to actively participate in the interview process and raise their own questions.

Respondents' selection criteria were as follows: homogeneity, comprehensive information coverage, and informed consent to participate in the survey. The first author, who was a member of the Chinese swimming team's safeguarding team, had sufficient time and access to the athletes. Consent was obtained from the coaches of each interviewee, with a detailed explanation of the ongoing research and the option to accept or refuse participation at any time. Final consent was obtained from all coaches and interviewees.

Six interviewees participated in the study, with Table 2 displaying the information gathered from the interviews. The demographic characteristics examined included the participants' ID, gender, age, training years in competitive sports, and career-best performance as swimmers. The interviews took place in an office setting, scheduled at times when all participants in a calm state of mind, without considering their training schedules., lasting between 30 to 60 min.

Before the interviews, we asked the participants to sign an informed consent form, assuring them the data collected would be used only for academic research and that their personal information would be protected. We also asked for their consent to be recorded. Next, we explained the purpose and contents of the interviews. We then proceeded with based on the interview outline, which included topics such as "mental state during the preparation period" and "strategies for coping with competition anxiety." Finally, we organised the data collected from the interviews.

2.4 Statistical analysis

visual inspection of histogram was used to test the normality of the sample. We used percentages, means, and standard deviations to analyse demographic information, trait anxiety, state anxiety characteristics, and data distribution of the samples. Independent t-tests were conducted to explore the variability of trait anxiety and state anxiety across different demographics and the differences in competitive anxiety across various sport performances. One-way analysis of variance (ANOVA) was used to explore the variability of state anxiety under different time points. Pearson's correlation tests were used to investigate the correlations between trait anxiety and state anxiety in different contexts as well as the correlations between various dimensions of state anxiety during periods of high training volume. Setting $p < 0.05$ as statistically significant. Using the statistical package Statistical Package for the Social Sciences (SPSS) - IBM 22.0 (SPSS Inc., Chicago, IL, United States). Datas are presented using tables.

3 Results

Table 3 showed that no significant difference between male and female swimmers in trait anxiety and state anxiety dimensions ($p > 0.05$). However, on average, male swimmers had higher levels of both trait anxiety and state anxiety compared to female swimmers, but also exhibited higher levels of self-confidence.

Previous research has emphasised the importance of investigating the impact of competitive anxiety levels on sports performance. According to Ruiz-Navarro et al. (2023), this study classifies participants into two groups based on their World Aquatics Points at the Fukuoka World Championships and the Hangzhou Asian Games to distinguish between successful and unsuccessful performances. The classification criteria are as follows:

i) The first level is based on the A qualifying standards set to participate at the international events, which correspond to ≥875 World Aquatics Points. ii) The second level is based on the B qualifying standards set to participate at the international events, which correspond to 794 World Aquatics Points.

TABLE 3 Gender differences in trait anxiety and competitive anxiety ($N = 20$).

	Gender (M ± SD)		t	p
	Male	Female		
Trait anxiety	46.40 ± 10.69	42.00 ± 6.02	1.134	0.272
Cognitive anxiety	6.85 ± 1.81	6.50 ± 1.92	0.840	0.404
Somatic anxiety	7.03 ± 2.06	6.83 ± 1.74	0.470	0.640
Confidence	5.45 ± 1.95	6.13 ± 2.08	−1.499	0.138

TABLE 4 The difference of competitive anxiety under sports performance in T2 ($N = 20$).

	World aquatics points (M±SD)		t	p
	Level 1 (n=11)	Level 2 (n=9)		
Cognitive anxiety	7.36 ± 1.80	7.22 ± 0.97	0.211	0.835
Somatic anxiety	7.55 ± 1.92	8.11 ± 1.27	−0.758	0.458
Confidence	8.36 ± 2.42	7.89 ± 0.93	0.554	0.586
Trait anxiety	45.00 ± 6.84	43.22 ± 11.00	0.443	0.663

T2 is anxiety levels were measured 30 minutes before the Fukuoka World Championships.

TABLE 5 The difference of competitive anxiety under sports performance in T3 ($N = 20$).

	World aquatics points (M ± SD)		t	p
	Level 1 (n=14)	Level 2 (n=6)		
Cognitive anxiety	6.64 ± 1.78	7.00 ± 0.89	−0.462	0.650
Somatic anxiety	6.93 ± 1.90	7.67 ± 1.03	−0.888	0.386
Confidence	7.43 ± 2.21	7.17 ± 0.75	0.280	0.783
Trait anxiety	45.43 ± 9.41	41.33 ± 6.77	0.958	0.351

T3 is anxiety levels were measured 30 minutes before the Hangzhou Asian Games.

TABLE 6 The difference of state anxiety at different points in time ($N = 20$).

	Different points in time (M ± SD)				F	p
	T0	T1	T2	T3		
Cognitive anxiety	5.00 ± 1.75	6.55 ± 1.00	8.15 ± 1.39	7.00 ± 1.75	15.074	<0.001**
Somatic anxiety	5.25 ± 2.17	7.45 ± 1.61	8.10 ± 1.21	6.90 ± 1.21	11.637	<0.001**
Confidence	6.75 ± 1.62	4.85 ± 1.46	4.15 ± 1.27	7.40 ± 1.82	19.552	<0.001**

All participants completed the MRF-3 pre-test in a quiet setting, establishing the baseline value (T0). A random measure of competitive anxiety during a high-volume training session was recorded as T1. Anxiety levels were measured 30 minutes before the Fukuoka World Championships (T2); and 30 minutes before the Hangzhou Asian Games was recorded (T3); * p<0.05; ** p<0.001.

There was no significant difference in competitive anxiety between swimmers at the Fukuoka World Championships and the Hangzhou Asian Games based on sports performance (World Aquatics points). However, on average, athletes who performed well at the Fukuoka World Championships had higher cognitive anxiety but lower somatic anxiety. In contrast, athletes who excelled at the Asian Games exhibited lower levels of state anxiety (Tables 4, 5).

Table 6 shows that significant differences were found in all dimensions of competitive anxiety at different time points ($p < 0.01$). Competitive anxiety was highest during the World Championships, followed by the Asian Games period and the high training volume period, all of which were higher than the baseline values.

Figure 1 display the relationships between trait anxiety and state anxiety at different time points, the r coefficient and significance are shown in the figure. The findings indicate that cognitive anxiety and somatic anxiety are positively correlated with trait anxiety, while self-confidence is negatively correlated with trait anxiety ($p < 0.05$).

Further analysis of the correlations among the dimensions of competitive anxiety revealed that cognitive anxiety was positively correlated with somatic anxiety and negatively correlated with self-confidence ($p < 0.05$).

Based on the correlation between trait anxiety and competitive anxiety, covariates were added to the regression analysis. The results showed that training years positively correlated with cognitive anxiety during the World Championships; training years positively correlated with somatic anxiety during the Asian Games (Tables 7, 8).

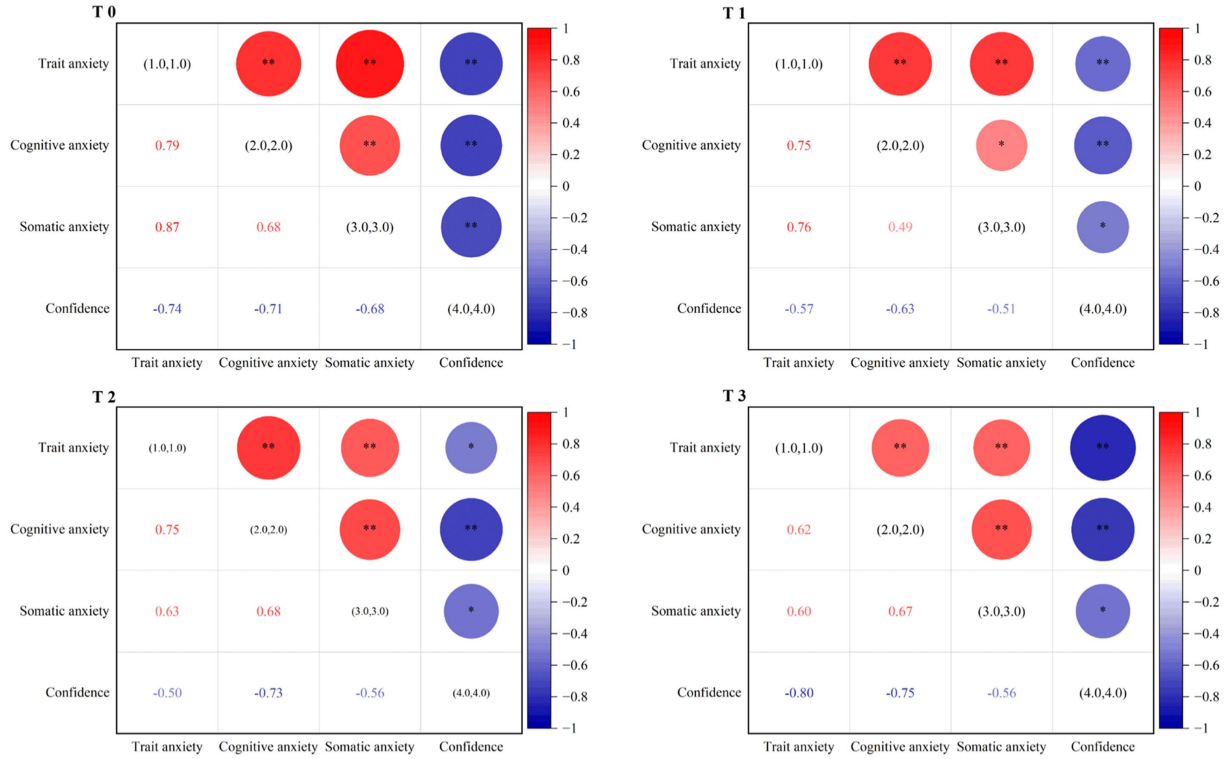

FIGURE 1
Correlation of competitive anxiety and trait anxiety in T0, T1, T2, and T3. All participants completed the MRF-3 pre-test in a quiet setting, establishing the baseline value (T0). A random measure of competitive anxiety during a high-volume training session was recorded as T1. Anxiety levels were measured 30 minutes before the Fukuoka World Championships (T2); and 30 minutes before the Hangzhou Asian Games was recorded (T3); *p<0.05; **p <0.01.

TABLE 7 Linear regression analysis during world championships.

	Unstandardized coefficients		Standardized coefficients	*t*	*p*	Collinearity diagnostics	
	B	*SE*	*Beta*			VIF	Tolerance
Constant	0.442	1.361	–	0.325	0.750	–	–
Gender	0.013	0.396	0.005	0.033	0.974	1.260	0.794
Age	−0.068	0.236	−0.040	−0.288	0.777	1.123	0.891
Training years	0.768	0.261	0.457	2.940	0.010*	1.425	0.702
Trait anxiety	0.143	0.022	0.903	6.471	<0.001**	1.147	0.872
R^2	0.745						
Adjust R^2	0.677						
F	$F(4,15) = 10.962$, $p = 0.000$						
D-W	1.448						

Dependent variable: cognitive anxiety.
VIF is designed to determine collinearity problems, and a value less than 5 indicates no collinearity. Tolerance = 1/VIF and the value less than 0.2 indicates collinearity; * p<0.05; ** p<0.001.

External training load was assessed by the total number of kilometers of the sessions. Internal training load was assessed by multiplying the athlete's "rating of perceived exertion" (RPE, on a 1–10 scale) obtained 30 min after the completion of the training session by the duration (in minutes) of the session (Wallace et al., 2009).

Table 9 showed significant positive correlations between external and internal loads and the cognitive and somatic anxiety, and negative correlations with confidence during high volume training. This suggests that the level of competitive anxiety increases as external and internal loads increase.

4 Discussion

According to this study, there is no significant difference in trait anxiety and competitive state anxiety between male and female swimmers. This finding is consistent with the results of Guillén and

TABLE 8 Linear regression analysis during Asian games.

	Unstandardized coefficients		Standardized coefficients	*t*	*p*	Collinearity diagnostics	
	B	*SE*	*Beta*			VIF	Tolerance
Constant	0.605	1.457	–	0.415	0.684	–	–
Gender	0.192	0.423	0.082	0.454	0.656	1.260	0.794
Age	−0.140	0.252	−0.094	-0.555	0.587	1.123	0.891
Training Years	0.758	0.280	0.517	2.708	0.016*	1.425	0.702
Trait anxiety	0.109	0.024	0.789	4.609	<0.001**	1.147	0.872
R^2	0.616						
Adjust R^2	0.514						
F	$F(4,15) = 6.019$, $p = 0.004$						
D-W	2.027						

Dependent variable: somatic anxiety.
VIF is designed to determine collinearity problems, and a value less than 5 indicates no collinearity. Tolerance = 1/VIF and the value less than 0.2 indicates collinearity; * $p<0.05$; ** $p<0.001$.

TABLE 9 The correlation between training load and competitive anxiety at high training volume.

	Cognitive anxiety	Somatic anxiety	Confidence	External load	Internal load
Cognitive anxiety	1				
Somatic anxiety	0.494*	1			
Confidence	−0.626**	−0.508*	1		
External load	0.831**	0.724**	−0.701**	1	
Internal load	0.743**	0.757**	−0.629**	0.824**	1

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

Álvarez-Malé (2010). The reason for this lack of variability may be that the sample comprises the top elite swimmers in the country. These athletes have honed their skills through extensive competitive experience, leading to a leveling of anxiety levels between genders.

> *Interviewee A3 said, "Everyone will anxiety in a competition, they just show it to a different degree or anxiety about different things, as well as different means of regulating it." A4 expressed her opinion based on gender differences, "Who says women are not as good as men? Gender may lead to personality differences, but at this (top) level, girls perform just like men, hahaha."*

This is an ongoing debate in the academic community about whether gender differences in competitive anxiety exist. While most studies indicate that female athletes generally have higher levels of competitive anxiety than male athletes (Amaro and Brandão, 2023), results can vary depending on the sport and population studied. Statistics show that since the Olympic Games, 80% of the medals won by the China's swimming delegation have come from women's events. China's women's swimming team has consistently excelled on the world stage often leading in competitiveness (Tan and Liu, 2003). since there is evidence in the literature that young swimmers of both sexes have similar characteristics of anxiety (Silva et al., 2017).

Yerkes' inverted U-curve theory suggests that athletes perform best when their competitive anxiety is kept at an optimal level (Lee et al., 2020). This controlled anxiety can positively stimulate the nervous system, enhancing physical performance. In facing high-level swimmers worldwide, some athletes self-regulate to maintain their competitive anxiety at this moderate level, achieving better results (Alavizadeh et al., 2023). This study found that swimmers with strong performances have higher cognitive anxiety, but lower somatic anxiety compared to others. Swimmer A5, who broke his personal best in the World Championships, said, *"I was especially excited to be at the World Championships and watch so many masters. If you ask me if I was nervous or anxious, the answer is yes, but I seized at the chance to prove myself, and I felt as if I had been helped by God during the competition."* These findings corroborate previous research, which showed that athletes participating in national and international competitions had lower SA scores, leading to an increase in performance (Souza et al., 2012; Silva et al., 2019).

This study shows significant differences in athletes' competitive anxiety at different times. During the World Championships, swimmers experienced the highest levels of competitive anxiety, followed by the Hangzhou Asian Games and then the high training volume sessions. Psychology believes that anxiety is realised through cognitive evaluation, where athletes compare their technical, tactical, and psychological strengths with their opponents. When facing a particularly strong opponent, athletes may feel they have little chance of winning, leading to high psychological pressure and competitive anxiety (Zhang, 2001). Some scholars noted that in different levels of competitions, factors such as the strength of their opponents, Athletes' personality traits and their internal psychological activities translate into external behaviours (Martens et al., 1990), resulting in significant differences in anxiety levels (Alavizadeh et al., 2022). The World Championships represent the pinnacle of swimming events, with the number of medals won serving as an indicator of a country

or region's competitive level (Sun and Zhao, 2023). The Fukuoka World Championships, being a major event before the 2024 Paris Olympics, attracts significant attention from various countries, reflecting their preparation for the upcoming Olympics. The results of related studies show that athletes with more training years have a higher cognitive anxiety, because they are afraid of losing (Silva et al., 2019).

According to the interview results, *swimmer A1 who has 19 years of training said, "The Fukuoka World Championships is the last world-class event before the Paris Olympics, I have to go all out to test my preparation and see how I compare to the world's top athletes. I am not too worried about the Asian Games, I am aiming for a gold medal, but rather to make an impact on MVP.* "So, most athletes exhibited a high heart rate, sweating, and a heightened nervous system activity before the Fukuoka World Championships.

The Hangzhou Asian Games marks the third time China has hosted the largest international multi-sport event in Asia (Zhang and Cai, 2023). As a major event held "at home," it has gathered significant expectations from various sectors. However, given the dramatic improvement in the level of Chinese swimmers and their obvious competition advantage in Asia, athletes' internal motivation and pre-competition self-confidence were much stronger. By boosting self-confidence, athletes can optimise their performance (Kang and Jang, 2018). Consequently, better sports performance at the Asian Games correlated with lower levels of competitive anxiety, with more athletes reaching Level 1 than at the World Championships. This aligns with Terry's findings, which suggest that athletes exhibit lower anxiety, higher self-confidence, and more positive attitudes and states when competing in home games (Terry and Parsons-Smith, 2021).

> A2 commented, *"The Asian Games is a home event, and I cannot afford to be embarrassed. I am not too anxious about the level of my opponents. My friends and family will be there to cheer me on, so I'm determined to win this tournament to satisfy those who support me."*

The present study demonstrated that high training volumes increased competitive anxiety in swimmers, which is consistent with previous findings (Chortane et al., 2022). Specifically, high training volumes can push athletes into an overtrained state, resulting in high RPE values, which elevate psychological fatigue and increase both cognitive and somatic anxiety (Collette et al., 2018). Typically, the body's sympathetic and parasympathetic nerves balance each other, but during high training volumes, athletes experience heightened sympathetic activity, increased heart rate, and blood pressure. They also tend to hold their breath, resulting in low oxygen levels and increased muscular and mental tension (Williams et al., 2008). Scholars generally agree that athletes' emotions are related to training load (Meeusen et al., 2013), this study suggests the increase in somatic and cognitive anxiety may lead to a decline in athletes' self-confidence.

Athlete A6 remarked, *"These intense training sessions are really exhausting and frustrating, but they are necessary to win and improve. If I skip them, I cannot swim well, and that makes me anxious. It's a vicious cycle."* Studies have shown that muscle fatigue from high training volumes can prevent athletes from completing their training load, leading to a decline in well-being and self-confidence (Morgan and Hayward, 1988). According to researches, as training volume increases, athletes' unhappiness rises, causing changes in thoughts, actions, and physiological responses. This decline in coping capacity affects their ability to meet goals, resulting in significantly decreased self-confidence (Chortane et al., 2022).

The present study demonstrated that, regardless of the moment of training and competition, state anxiety and trait anxiety in our elite swimmers were significantly positively correlated. This means athletes with high levels of trait anxiety also exhibited high levels of state anxiety, supporting Scanlan and Lewthwaite's (1986) findings. Someone's results further showed that athletes with high trait anxiety experienced a greater increase in state anxiety during periods of heightened training volume (O'Connor et al., 1989). The interaction theory of anxiety, attentional control theory, and processing efficacy theory all agree that state anxiety results from a multidirectional interaction between an individual and their environment. These theories suggest that in stressful environments, such as competitions, athletes with high trait anxiety display higher state anxiety compared to those with low trait anxiety (Morris et al., 1981).

This is clearly illustrated by athlete A6: *"I often feel that I am not suited for competitive sports. I usually get anxious over small things, so during major competitions, I feel like I'm going to explode, but look at xx, who is always carefree, never overthinking, he can even fall asleep before an event, I really admire that level of relaxation."*

Trait anxiety in athletes is persistent and varies individually as a personality trait. In contrast, competitive anxiety is a psychological state that occurs in specific contexts. These two forms of anxiety are related; high levels of trait anxiety can trigger more intense state anxiety in response to particular situations and psychological stimuli.

Translating research results into practical implications involves tailoring targeted interventions for individual elite swimmers. By identifying anxiety levels during different training and competition phases, sports psychologists, practitioners and safeguarding teams can take timely preventive measures to enhance effectiveness. Additionally, the environment surrounding elite swimmers must be ready to provide social support, especially during periods of increased pressure. Coaches should strengthen their psychological knowledge, understand the changing patterns of swimmers' personality traits and anxiety states, and guide athletes in coping with competitive anxiety. It is also recommended to incorporate stage-by-stage simulated competitions into the training cycle to replace practice with competition, which can improve athletes' motivation and self-confidence, and achieve desensitization (Chen et al., 2024).

One can note a few limitations to this research. The effect of other physiological-psychological variables (e.g., heart rate, blood lactate, heart rate variability) on competitive anxiety at various moments in the study remains unclear. Future studies could enhance the research by supplementing questionnaires with physiological-biochemical tests. Additionally, the number of subjects was limited because the study's inclusion criteria required athletes selected for both the Fukuoka World Championships and the Hangzhou Asian Games in a single event. Future research could broaden the participant pool by selecting from the Olympic delegation. This study quantified results using World Aquatics Points. However, despite investigating changes in swimmers' competitive anxiety at different points in time, the study was limited by its short duration. Further research is needed to examine changes in competitive anxiety levels at different stages of swimmers' careers.

5 Conclusion

This study examined the characteristics of competitive anxiety impact sports performance across four different phases of competitive preparation, alongside its correlation with trait anxiety. Main results underline the competitive anxiety has different characteristics in the preparation cycle. It also provides support the trait anxiety is highly correlated with competitive anxiety. Responding to the findings of this study, professionals can develop personalised interventions aimed at managing swimmers' competitive anxiety and enhancing their mental well-being, mitigate negative psychological impacts and boost self-confidence, thereby optimising their sports performance.

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 Sports Science Experiment Ethics Committee, Beijing sport 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

YZ: Conceptualization, Data curation, Formal analysis, Investigation, Software, Writing – original draft, Writing – review & editing. ZJ: Software, Visualization, Writing – review & editing. YW: Resources, 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.

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EDITED BY
Marianna Alesi,
University of Palermo, Italy

REVIEWED BY
Tim Heemsoth,
University of Flensburg, Germany
Jan Erhorn,
University of Oldenburg, Germany

*CORRESPONDENCE
Felix Kruse
✉ felix.kruse@phsg.ch

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Dimensionality of instructional quality in physical education. Obtaining students' perceptions using bifactor exploratory structural equation modeling and multilevel confirmatory factor analysis

Felix Kruse[1]*, Sonja Büchel[2] and Christian Brühwiler[3]

[1]Institute of Physical Education, Sports and Health, St. Gallen University of Teacher Education, St. Gallen, Switzerland, [2]Institute of Education and Professional Studies, St. Gallen University of Teacher Education, St. Gallen, Switzerland, [3]Vice-President's Office for Research & Development, St. Gallen University of Teacher Education, St. Gallen, Switzerland

Background: In research on instructional quality, the generic model of the three basic dimensions is an established framework, which postulates that the three dimensions of classroom management, student support and cognitive activation represent quality characteristics of instruction that can be generalized across subjects. However, there are hardly any studies that examine if the three basic dimensions model could represent a suitable approach to measure instructional quality in physical education. Based on an extended model of the basic dimensions, a measurement model of instructional quality for physical education is presented, which integrates different theoretical approaches from the fields of educational and psychological research as well as different subfields of sports science in order to test the factorial structure of the corresponding measurement model.

Methods: 1,047 students from 72 seventh to ninth grade classes from different German-speaking Swiss cantons participated in the study. The conceptualization of the instrument is based on a hybrid approach that integrates generic and subject-specific characteristics. The simultaneous analysis at the individual and class level using MCFA was supplemented by more complex methodological techniques within the relatively new B-ESEM framework at the individual level.

Results: The postulated five-factor structure was initially tested using ICM-CFA and showed a good model fit (e.g., $\chi^2/df = 2.32$, RMSEA = 0.03, CFI = 0.97, TLI = 0.97, SRMR = 0.04). MCFA revealed a differential factorial structure at both levels of analysis with five factors at the individual level and four factors at the class level (e.g., $\chi^2/df = 2.23$, RMSEA = 0.03, CFI = 0.96, TLI = 0.96, SRMR within = 0.04, SRMR between = 0.10). ESEM and B-ESEM outperformed the ICM-CFA and showed an excellent model fit (B-ESEM: $\chi^2/df = 1.19$, RMSEA = 0.01, CFI = 1.00, TLI = 1.00, SRMR = 0.01). Inter-factor correlations and factor loadings are largely in line with expectations, indicating arguments for construct validity.

Discussion: The study represents a substantial contribution in linking physical education and the generic research on instructional quality. Overall, strong arguments for the factorial structure of the measurement model were

demonstrated. The study can be interpreted as a first step in a multi-step procedure in terms of further validity arguments.

KEYWORDS

instructional quality, students' perceptions, physical education, MCFA, ESEM, B-ESEM, teaching quality

1 Introduction

Instructional quality has proven to be one of the strongest predictors of educational outcomes like achievement and motivation (e.g., Seidel and Shavelson, 2007). Although there is a consensus on the multi-dimensionality of instructional quality (e.g., Klieme et al., 2001; Kyriakides and Creemers, 2008), current contributions deal with the differentiation of various dimensions, especially regarding different subjects (Praetorius et al., 2020a). Even if theoretical background and measurement diverge strongly (Praetorius et al., 2018; Bijlsma et al., 2021), the consensus may be that at least three dimensions of instructional quality can be distinguished (Pianta and Hamre, 2009; Klieme, 2013). Although this conception is particularly appealing for its parsimony, recent contributions confront the model with the question of whether this threefold structure is comprehensive enough (Praetorius and Charalambous, 2018; Kleickmann et al., 2020). Whereas the majority of empirical evidence can be found in mathematics and science education (Praetorius et al., 2020a,b,c), there is a lack of empirical evidence for physical education (PE). For PE, which differs from predominantly cognitive subjects in various aspects (e.g., the relevance of motor functions), the question arises to what extent generic conceptualizations can be transferred and to what extent they should be adapted and supplemented in a subject-specific way. However, in connecting PE to the generic research on instructional quality, it seems to be a suitable approach to use the evidence already available from other subjects to the best potential. Accordingly, the present study investigates the dimensionality of instructional quality in PE using the combination of generic and subject-specific aspects. Since we postulate that interindividual differences hold special significance in PE, in addition to the simultaneous analysis at the individual and class level using multilevel confirmatory factor analysis (MCFA), relatively new promising methodological approaches are applied at the individual level using a combination of Bifactor Modeling and Exploratory Structural Equation Modeling (B-ESEM).

1.1 Students' perceptions of instructional quality

Ensuring that scientific quality criteria are met is a central issue in research on instructional quality (Göllner et al., 2021). Together with external observations, students' perceptions are one of the central data sources for assessing instructional quality. While external observations provide a higher degree of objectivity and can make evidence-based assessments (assuming observers have been well trained), to be truly reliable, these must be conducted by several observers over several lessons (Praetorius et al., 2014). Thus, external observation can generally be described as time-consuming and relatively expensive. While external observation often tend to be considered as the gold standard, students' perceptions have been shown to have the potential to provide reliable and valid information for the study of instructional quality (Fauth et al., 2014; Kane et al., 2014). Students contain a long-term experience with the teacher, are able to compare teachers inter-individually and being highly economical to conduct. Moreover, the large number of observers could improve the reliability at class level (e.g., Kane and Staiger, 2012; Fauth et al., 2020). Furthermore, the use of student perceptions provides the opportunity to examine not only data at the class level, but also at the individual level, so that the information regarding differences within classes can be examined. Accordingly, there are additional possibilities for a deeper insight into the data, which can be used to address research questions that focus on inter-individual differences. However, using students' perceptions of their instructional quality (SPIQ) in research can be described as a complex endeavor. Researchers concerned with the measurement of SPIQ are confronted with the question of what has to be taken into account to ensure that they represent reliable and valid measurements. That is, for example, the interpretation of the items by the recipients in relation to the intention of the test constructor (Karabenick et al., 2007), the issue of low agreement with other data sources (Kunter et al., 2007; Wagner et al., 2016), the idiosyncratic nature of students' ratings (Göllner et al., 2018, 2021), the generalizability of domain-independent assessments or the high inter-factor correlations of theoretical distinct instructional quality dimensions (Röhl and Rollett, 2021). With regard to the last point, it can be stated that although in principle there is evidence for the factorial validity of SPIQ, studies report very high inter-factor correlations of the theoretically divergent dimensions. For example, Krammer et al. (2019) report an inter-factor correlation of up to 0.95 at the individual level and 0.93 at the class level, Wagner et al. (2013) report values of up to 0.74 at the individual and 0.94 at the class level, and Wisniewski et al. (2020) report values of up to 0.89 at the individual and 0.93 at the class level. Some researchers, looking at the specifically used items in the different studies, tried to explain some of the mentioned challenges in the use of SPIQ. For example, regarding the reference of the item in the context of the low agreement of different data sources (Fauth et al., 2020) or regarding halo effects as a possible explanation for high inter-factor correlations (Röhl and Rollett, 2021).

1.2 Dimensionality of instructional quality

Concerning the measurement of instructional quality, a variety of approaches exist, whereby the question of parsimony as well as comprehensiveness arises. Certainly, the complexity of teaching must be reduced, so that it becomes manageable in some way. On the other

side, the important teaching aspects for the achievement of educational goals should be incorporated (Praetorius et al., 2020c). A prominent model of instructional quality in the context of condensing key instructional aspects as parsimoniously as possible have been developed by Klieme et al. (2001). The model includes the three basic dimensions (TBD) of *classroom management*, *supportive climate* and *cognitive activation*. *Classroom management* can be described as a prominent construct in educational research and includes the strengthening of desirable student behaviors by, for example, communicate clear rules, and preventing undesirable student behavior, e.g., by monitoring or designing transitions (e.g., Kounin, 1970; Hochweber et al., 2014). These behaviors may manifest in low-disruptive classroom environments, which are like to promote the transition of potential learning time into real learning time (Kuger et al., 2016). Provided that it is used, classroom management is considered to be central to student learning success and may foster student motivation as well (Rakoczy et al., 2007; Seidel and Shavelson, 2007). *Student support* is characterized by the student-teacher relationship and includes aspects such as caring behavior, support for autonomy or a positive approach to mistakes. Because of the emotional character of these factors, effects on social–emotional outcomes in particular are assumed (Fauth et al., 2014; Praetorius et al., 2018). Finally *cognitive activation* is based on constructivists views of learning and contains addressing students' prior knowledge, challenging tasks, stimulation of cognitive conflicts or the engagement of students in higher-order thinking processes (Lipowsky et al., 2009; Baumert et al., 2010).

The model of the three basic dimensions is particularly appealing because of its theoretical foundation as well as the parsimony of the model (Praetorius et al., 2020b). In recent times, however, the question has arisen repeatedly as to what extent the three dimensions are comprehensive enough, or whether it would make sense to add further dimensions. In their review, Praetorius et al. (2018) found that only half of the previous findings were consistent with the model assumptions and accordingly suggest further development of the three basic dimensions model. Kleickmann et al. (2020) proposed a for PE interesting addition of a fourth dimension, namely cognitive support. Cognitive support is based on theories from cognitive psychology as well as social constructivist theories. Drawing particularly on cognitive load theory and the role of scaffolding in complex learning situations, cognitive support aims to reduce complexity and corresponding cognitive demands. Given this background, Puntambekar and Hubscher (2005) differentiate between an original and an evolved or current notion of scaffolding. Kleickmann et al. (2020), following this literature, distinguish between adjusted support, which particularly involves the interaction of teachers and students by means of explaining, highlighting, and informative feedback, and blanked support, which relates more to a collective level by establishing clarity of goals or a clear structure. Since cognitive support can be understood as a significant instructional dimension, it would be surprising if no integration had taken place in the model of the three basic dimensions. Due to the heterogeneity of operationalizations of the model of the three basic dimensions (Praetorius et al., 2018), Kleickmann et al. (2020) compile different types of integration of cognitive support in previous work on the three basic dimensions, which can be divided into four types: First type contains no or only rudimentary consideration in the three basic dimensions. If considered, then as part of student support (examples include Fauth et al., 2014; Decristan et al., 2015). The second type provides a more comprehensive integration of cognitive support into student support. In this case, student support is divided into a cognitive and a motivational component, with the former involving the reduction of cognitive demands and the latter involving social relatedness and autonomy support (examples include Kunter and Voss, 2013; Hochweber and Vieluf, 2018). In the third type, cognitive support is integrated as part of classroom management; especially as lesson clarity or structure (examples include Klieme et al., 2001; Taut and Rakoczy, 2016). Finally, the fourth type subsumes cognitive support under the basic dimension of cognitive activation. The Classroom Assessment Scoring System (CLASS; Pianta and Hamre, 2009) can be mentioned as an example, in which aspects such as the quality of feedback or the clear presentation of content (cognitive support) as well as the promotion of higher-order thinking (cognitive activation) are integrated. The empirical analysis of the postulated four-factor structure of classroom management, motivational support, cognitive support, and cognitive activation using SPIQ for science education shows an adequate model fit, representing the favored model over the alternative models (types 2–4). However, a closer look at the items of the study by Kleickmann et al. (2020) shows that the operationalization of cognitive support includes in particular the reduction of complexity in the sense of the occurrence of and help with comprehension problems as well as the clarity of goals. Therefore, further aspects such as modeling, explaining, or highlighting or the reduction of task difficulty are not or only marginally reflected. Due to this sparse operationalization as well as the theoretical differentiation of adjusted and blanked support, the question arises to what extent these two could also represent independent factors, representing a five-factor structure. Considering other models of instructional quality, such a division can also be observed, for example in the teaCH model in which aspects of adjusted and blanked support are largely modeled separately (e.g., Kane and Staiger, 2012; Wisniewski et al., 2020). These two components of cognitive support appear to be a potent extension of the model of the three basic dimensions in order to integrate significant PE-specific aspects of instructional quality.

1.3 Instructional quality in physical education: what to adapt, what to extend?

1.3.1 Characteristics of physical education and corresponding objectives

Existing instruments of instructional quality vary widely in the scope and selection of relevant dimensions (e.g., Charalambous and Praetorius, 2018; Bijlsma et al., 2021). This is not least the case since it can be described as difficult to neither under-represent a construct nor to include aspects that are less relevant to the target criterion (AERA et al., 2014). Correspondingly, the conceptualization of instructional quality should be carried out in terms of the intended educational goals and in relation to the scope of the respective study. Even if there is no international consensus, the goals of PE can be described as at least partly different to other subjects. In this context, cognitive outcomes are less relevant to most other subject matters. Instead, PE provides a unique contribution to the education of students in the context of motor competence (e.g., Rink, 2014). However, it seems important to emphasize that PE does not necessarily aim at peak performance of the students' motor competencies but rather target basic motor competencies that could be shown to be significant

prerequisites for physical activity (PA) (McLennan and Thompson, 2015; Lopes et al., 2021). In this context, PE has great potential to promote PA not only during school hours, but also to acquire the necessary motor competencies and motivation to be physically active outside of school (e.g., Jaakkola et al., 2017). Given that physically inactive children are more likely to become physically inactive adults (Telama, 2009), in line with McLennan and Thompson (2015), quality PE has great potential to be the foundation of lifelong participation in PA, which in turn, can be considered a key health variable associated with multiple physical health benefits, such as cardiovascular and metabolic health, as well as mental and cognitive health benefits (Janssen and LeBlanc, 2010; Poitras et al., 2016; Biddle et al., 2019; Whooten et al., 2019). Besides motor competencies, motivational variables play a pivotal role in PE. Especially a lack of enjoyment and low perceptions of physical competence can be identified as particular important influencing factors regarding PA (Sallis et al., 2000; Babic et al., 2014; Crane and Temple, 2015; Jaakkola et al., 2017). Therefore, as one key goal of PE, students should be offered a motivationally and emotionally supportive environment in which they can adequately develop motor competencies to stay physically active across the lifespan. It must be noted, however, that even though it is assumed that enjoyable experiences in PE can create a positive emotional state that may encourage participation in PA during leisure time, which is also supported by the trans-contextual model (Hagger et al., 2003), for which there is some empirical evidence (Hagger et al., 2009), it does not fully account for the affective responses that may partly explain the relationship between PE motivation and PA participation. It is noteworthy that enjoyment in PE accounted for only 10–15% of PA participation, suggesting that PA participation is also influenced by various other factors (Sallis et al., 2000) in addition to enjoyment in school PE.

Considering the mentioned objectives of PE, the following section summarizes relevant evidence on instructional variables for PE in the context of the generic model of the three basic dimensions and the highlighted outcomes of motivation, perceived competence and motor competencies. However, as the number of variables under consideration is large and the contexts and settings of studies varies widely, the present study can only represent a selection of potentially significant factors.

1.3.2 Motivational psychology approaches

Motivational processes play a critical role in physical education (PE) by shaping how students engage with and benefit from the instructional environment. Integrating principles from motivational psychology can significantly enhance instructional quality and student outcomes. Drawing on self-determination theory (Deci and Ryan, 2000), a key element in creating an effective PE environment is the fulfillment of the basic psychological needs of autonomy, competence, and relatedness. The support of basic psychological needs can be seen as typical aspects of an instructional quality understanding and is even part of the theoretical foundation of the same (for TBD, see Praetorius et al., 2018). Need supportive practices are positively associated with need satisfaction, more autonomous SDT types of regulation as well as adaptive outcomes (e.g., enjoyment and physical activity intentions), whereby teachers have more potential to influence students' autonomy and competence compared to students' relatedness (Vasconcellos et al., 2020). Furthermore, the relatedness between peers seems to play an important role in the development of intrinsic motivation (Vasconcellos et al., 2020; Kruse et al., 2024). In addition to fulfilling these basic psychological needs, establishing a mastery-oriented motivational climate is essential for fostering students' intrinsic motivation and long-term engagement in physical activities. This climate emphasizes personal improvement, effort, and learning rather than competition and comparison with others. By focusing on personal goals and self-improvement, students are encouraged to view challenges as opportunities for growth, which fosters intrinsic motivation (Ames, 1992; Soini et al., 2014), which is in line research on teachers' individual reference norm orientation (e.g., Dickhäuser et al., 2017). Incorporating these motivational elements into PE is not without its challenges. The physical and often public nature of PE activities can make students feel vulnerable, leading to heightened emotional responses such as anxiety or embarrassment. Teachers must skillfully manage these emotional dynamics to maintain a positive and productive learning environment (Gerlach et al., 2007; Sabiston et al., 2014). An emotionally and motivationally supportive classroom environment may help to mitigate negative emotions, encouraging students to participate more actively and confidently. In addition, positive feedback, which focuses on successful performance and provides constructive guidance, significantly boosts students' sense of competence and motivation. For example, Badami et al. (2011) found that feedback following successful trials enhances intrinsic motivation more effectively than feedback after unsuccessful trials. This aligns with findings by Saemi et al. (2012), who demonstrated that learners receiving feedback on their successful attempts exhibited higher levels of perceived competence and intrinsic motivation compared to those who received feedback on their errors.

1.3.3 Classroom management

Regarding the specifics of classroom management in PE, many authors describe classroom management as more challenging than in other subjects, referring particularly to the difficult acoustics in the gym, the lack of pre-structured space compared to a classroom, the changing teaching locations, and the safety aspect (Chepyator-Thomson and Liu, 2003; Cothran and Kulinna, 2014; Baumgartner et al., 2020). Empirical evidence is primarily found in the area of measurement instruments of classroom management (Baumgartner et al., 2020, 2023) or oftentimes disruptive behavior (Krech et al., 2010) as well as regarding the prerequisites for disciplined behavior (Claver et al., 2020), whereas the effects of classroom management on student outcomes are more implicitly assumed. However, Bevans et al. (2010) highlight the impact of classroom management on student physical activity levels during PE.

1.3.4 Cognitive-motor support and cognitive-motor activation

While subject-specific additions and adaptations are less pronounced in classroom management and student support, they are considered most challenging for cognitive activation (Schlesinger et al., 2018) and, in context of this study, likewise for cognitive support. In contrast to the more cognitive shaped subjects, the connection between cognition and motor learning is of particular importance for PE. Accordingly, it is important to identify, to what extent these dimensions must be adapted to take this difference into account. From a neuroscience perspective, the interconnection of cognition and motor function can be underpinned by internal model theory. It posits that the process of motor control is closely linked to the construction

and updating of mental models that describe the relationship between actions and sensory feedback (Wolpert and Flanagan, 2016). These mental models serve as a frame of reference for monitoring and correcting movements and allow us to anticipate the effects of changes in the environment or body on our movements. The internal model is built through motor experience and can be updated through feedback from the environment (Shadmehr and Krakauer, 2008). It consists of various components that control the dynamics and stability of movements, such as prediction models based on sensory information and correction models that calculate and compensate for errors between actual and desired movement. By building and improving internal models through motor experiences, learners can optimize their movement skills and respond more quickly to new situations and environments. Internal model theory understands motor learning as an active process, as our movements influence our sensory information (Wolpert et al., 2011). It appears obvious that the generic dimensions of cognitive activation and cognitive support are therefore in no way to be understood without a motor complement. Therefore, in the following, the two dimensions are consequently termed cognitive-motor activation and cognitive-motor support. Even though a co-constructive learning situation is clearly not the scope of the internal model theory, it seems reasonable that by, e.g., gradually introducing students to more complex movements and providing feedback teachers can continuously improve and refine their internal models of movements.

For blanket cognitive-motor support, in line with a constraint-based perspective of motor learning (Renshaw et al., 2010), it can be assumed that by constraining the dynamic interplay of the performer, the task, and the environment through the guidance of the teacher, individualized support becomes facilitated. The emphasis on the role of teacher guidance of students in complex learning environments is congruent with theories of cognitive psychology, especially cognitive load theory, which aim to reduce complexity in learning situations (e.g., Kirschner et al., 2006). While scaffolding is relevant for both subcomponents, but especially for blanked support, teacher feedback is particularly relevant for adjusted support. In this context, feedback is one on the most researched instructional aspects in PE. However, the relevant literature on motor learning and motor control refers to augmented feedback, that is the information provided by sources outside the body, like visual, auditory and multimodal feedback (Moinuddin et al., 2021)—a term that does not appear in research on generic instructional quality but is necessary in PE because of its distinction from sensory feedback (Cole and Sedgwick, 1992). As in other subjects, (augmented) feedback can be considered an essential instructional factor for quality PE. Empirical findings show that augmented feedback can promote motivation and perceived competence (Mouratidis et al., 2008) as well as motor learning (Zhou et al., 2021). In the literature on motor learning, augmented feedback can be divided into information about the result of the movement (knowledge of result) and about the quality of the movement (knowledge of performance) (Lauber and Keller, 2014) as well as with regard to the temporal dimension in giving feedback immediately (concurrent feedback) and giving feedback after the execution of the movement (terminal feedback) (e.g., Moinuddin et al., 2021). It seems reasonable that the relevance for PE of the different types differs especially in relation to the corresponding sport. In long jump, for example, knowledge of result can be obtained largely without feedback from the teacher, whereas for esthetic criteria in gymnastics or dancing, external feedback on the result of the movements can be perceived as very significant. Verbally given feedback about knowledge of performance is most common in PE and can be divided in a prescriptive and a descriptive component (Schmidt et al., 2018; Petancevski et al., 2022). The two components aim at advising the learner to improve the movement as well as correcting movement errors. While positive effects of the prescriptive component on motor performance have been demonstrated in an adult population, Petancevski et al. (2022) emphasize the large positive effects of a combination of both components in their recently published systematic review. Accordingly, both components appear to be potentially relevant instructional aspects for PE. Furthermore, systematic reviews have also addressed the question of which subtypes (e.g., verbal, visual; informative, corrective, evaluative) of feedback support motor learning most strongly under certain conditions in PE (e.g., task complexity; skill level). The findings can be described as partially inconsistent, whereby in the case of verbal feedback, only corrective feedback proved to be effective for motor learning. However, it should be emphasized that the formats and contents of the underlying studies differ considerably (Zhou et al., 2021; Han et al., 2022).

With regard to cognitive-motor activation, limitations can be identified in the transfer to PE with regard to the concept of higher-order thinking. This circumstance is also relevant to adjusted cognitive-motor support, whereby research on focus of attention is particularly relevant. Research on focus of attention is mainly concerned with the question of whether an external focus of attention (focusing on movement effects) or an internal focus of attention (focusing on movement form) is more conducive to movement learning. The large majority of research indicates that an external focus of attention in different contexts, such as task type or age groups, leads to improved outcomes of both movement effectiveness (e.g., accuracy, balance) and movement efficiency (e.g., muscle activity, cardiovascular responses) (Wulf, 2013). Overall, an external focus of attention appears to be a beneficial condition for optimal motor learning. The assumption is that a learner's focus on the process of movement execution disrupts the automatic processes that control movement, resulting in lower motor performance. However, addressing this possible limitation of transferability seems to be a worthwhile endeavor in an empirical investigation.

Nesbitt et al. (2021) identified additional factors that are relevant within the extended model of the three basic dimensions in question, namely, developmentally sequenced activities, task-relevant cues, and emphasis on instruction and feedback on an individual basis. Furthermore, regarding the transfer of TBD to PE, a first instrument was presented by Herrmann (2019), which was complemented by a subject-specific motor activation dimension, based on the action-theoretical perspective of Niederkofler and Amesberger (2016). In doing so, Herrmann constructed and adapted items for PE in a subject-specific manner. However, a confirmatory analysis of the dimensionality of the model as well as further analysis has not yet been carried out so far.

1.3.5 The appropriate level of analysis

Combining the constructivist view of TBD and motor research on learning as an active, individual process it can be assumed that the degree of cognitive-motor activation and cognitive-motor support varies greatly between individuals and manifests itself differently in

the context of individual learning conditions. That is, a specific movement task may be strongly cognitively activating for one student, whereas it may be less cognitively activating for another student. Drawing on the social constructivist assumption of the zone of proximal development, it can be assumed for cognitive-motor activation that students must rather feel individually challenged in order to stimulate learning processes (Vygotsky and Cole, 1978; Rieser and Decristan, 2023). For aspects of adjusted cognitive-motor support, it seems reasonable that this focus on individual level might also apply. For instance, it can be assumed that a substantial part of the teacher's feedback is individualized and does not take place at the class level. According to these assumptions, it seems reasonable that cognitive-motor activation as well as adjusted cognitive-motor support should be more strongly conceptualized as individual-level constructs instead of classroom-level constructs (Marsh et al., 2012; Rieser and Decristan, 2023). In this respect, deviations of individuals from respective class means as inter-individual differences should considered as important indicators for adequate support of the teacher (Göllner et al., 2018). Here, the specific construct should be considered on a customized basis: If, for example, items were asked about disruptive behavior in the classroom, the degree of interindividual differences would presumably be significantly lower than would be the case for items about individual augmented feedback in the context of cognitive-motor support. Indeed, Wagner et al. (2016) were able to show high consistency in student ratings for constructs such as classroom management or goal clarity, whereas constructs such as autonomy support, with a stronger individual emphasis, showed low consistency. Identifying the appropriate level of analysis is an important issue. Lüdtke et al. (2009) clearly emphasize that the appropriate level of analysis depends on the specific research question. Taking into account that motivational processes play a significant role in PE and that these usually have low intra-class correlations, the importance of the individual level can be emphasized (Kunter et al., 2007; Lazarides and Ittel, 2012). Moreover, we would like to point out another possible condition for the choice of the level of analysis in PE. In contrast to other subjects, it can be assumed that inter-individual differences are particularly formative. PE is shaped by the reciprocal relationship of extracurricular and school sport practice. The former obviously has a great influence on the students' learning performance as well as on the overall performance heterogeneity within the class. Furthermore, extracurricular sports are largely organized in individual sports (e.g., soccer, dancing, and gymnastics), which exacerbates performance differences in PE. Taking, for instance, the subject of mathematics, there will be only a fraction of learners who participate in a mathematical recreational activity. If they do, it will probably be mostly not with strong limitation to a subfield of mathematics. Inter-individual differences thus seem to play a pivotal role in PE, which are not exclusively related to the achievement level but also to motivational aspects (e.g., strong interest in basketball, weak interest in dancing). In connection with the above-mentioned social constructivist views, the individual level for the dimension of adjusted cognitive-motor support, cognitive-motor activation and motivational-emotional support can be considered as particularly relevant. Students must be individually cognitively challenged and receive support related to their learning level, which should ultimately manifest itself in an improved motor learning performance as well as in an increase in intrinsic motivation of the students. These assumptions can also be supported by models of motor learning. The popular three-stages view (Fitts and Posner, 1967) can be used as an example. Overall, the interplay between cognition and motor systems occurs at different levels of movement learning. At the beginning of the learning process (cognitive stage), it is necessary for the learner to develop an understanding of the movement to be learned. Learners performing a movement task for the first time are confronted with the question of what actions, on an initially rather granular level, need to be performed in order to achieve the intended goal. This requires cognitive processing of the movement requirements and planning of the movement sequences. Learners attempt to develop appropriate strategies to realize adequate movement execution. This stage is likely to be characterized by a particularly high level of cognitive activity, supported by verbal feedback in particular (Fitts and Posner, 1967; Schmidt et al., 2018). Furthermore, it is characterized by a high increase and a high inconsistency in performance. Therefore, the cognitive stage is the most appropriate for teachers to support the learning process, e.g., through structuring and feedback. Once the understanding of the movement is in place, the motor implementation of the movement begins (fixation stage). Performance improvement is mostly gradual, less inconsistent and can persist over a long time. The focus is now less on the question of relevant movement patterns but more on the question of how movement execution can be optimized. The importance of instruction decreases, whereas the importance of sensory feedback increases. These two of the three stages already illustrate very well the importance of individual feedback, depending on the performance level of the student (Edwards, 2010; Braun et al., 2017). Considering the importance of basic motor competencies in PE, it quickly becomes apparent how relevant the cognitive phase is, since here the aim is not to perform at a higher level, but to refer to the participatory idea of PE (see also the ability to act; Gogoll, 2013).

1.4 Promising advanced methodological techniques

High inter-factor correlations between dimensions of instructional quality raise the question of whether students' perceptions can adequately distinguish between them, respectively, whether the different factors are strictly distinct (Scherer et al., 2016; Röhl and Rollett, 2021). In this context, the typical investigation of multidimensional instruments in psychological and educational research is based on confirmatory factor analysis (CFA). However, despite the various important contributions (Marsh et al., 2014), CFA is based on the Independent Cluster Model (ICM), in which cross-loadings between items and non-target factors are fixed to be exactly zero (e.g., Howard et al., 2016). Regarding the mentioned high inter-factor correlations of instructional quality dimensions, from a measurement perspective, not taking into account that items potentially belong to one or more other factors, can also be reflected in inflated inter-factor correlations as well as poor goodness-of-fit. Taking this into consideration, more flexible models such as exploratory structural equation modeling (ESEM) have recently been introduced, which overcome the unrealistic ICM assumptions and, conversely, represent a more realistic modeling approach. As its name already indicates, there are similarities between ESEM and conventional exploratory factor analysis (EFA) in that cross-loadings between items and all factors are allowed. However, ESEM differs

from EFA in that it incorporates features of structural equation modeling and therefore allows the evaluation of model fit indices, the assessment of measurement error, or the testing of measurement invariance. ESEM can thus integrate the best of both approaches, the EFA and the ICM-CFA, in one model. The lack of consideration of cross-loadings in the context of CFA can bring disadvantages, which are particularly important for constructs like instructional quality, where it is assumed that the different dimensions have conceptual overlaps. The examples of heterogeneous incorporation of cognitive support into different dimensions (see section 1.2) can be cited as a suitable example in this context. Specifically, ignoring cross-loadings can lead to biased results regarding inflated inter-factor correlations of factors as well as a reduction in goodness-of-fit indices (e.g., Marsh et al., 2020; Alamer, 2022). Accordingly, the high inter-factor correlations of the factors in the field of instructional quality would not necessarily have to be regarded as weak discriminant validity but may also indicate the disadvantages of the ICM assumptions. Further problems occur in the context of typical, subsequent adjustments in the context of ICM-CFA as a result of poor model fit (e.g., allowing measurement errors to correlate or removing items; Alamer, 2022). Removing items in this context can be seen as particularly difficult in the context of parsimonious modeling (such as the model of instructional quality in question). Especially, when the number of items measuring a construct is limited, each item contains important information about the construct, so that removing the item would distort the representation of the construct (Hair et al., 2019). Considering the advantageous features of ESEM, an application in the field of instructional quality research seems to be a promising approach.

The assessment of hierarchically ordered constructs, in which items reflect both specific dimensions (e.g., cognitive-motor activation) as well as a global overarching construct (instructional quality) can be considered a second source of construct-relevant psychometric multidimensionality (Reise et al., 2010; Morin et al., 2020). In this context, higher-order models can be distinguished from bifactor models. In higher-order models, the indicators reflect the orthogonally set first-order factors, which in turn reflect the second-order factor. Accordingly, the second-order factor has no direct effect on the indicators, but only indirectly via the first-order factors. In bifactor models, the higher-order global factor (G factor) directly influences the indicators [e.g., Reise et al., 2010; see also Schmid and Leiman (1957) transformation procedure (SLP)]. In the context of ICM-CFA, this would mean that all item loadings of the G factor as well as of the specific factors (S factors) would be freely estimated, with the factors set orthogonally as in higher-order models (Morin et al., 2020). The variance in the bifactor model can thus be divided into a global component of the shared variance of all indicators, additional specific components of the shared covariance of a subset of specific items, and a measurement error. Accordingly, the restrictive assumption of higher-order models that the association between indicators and higher-order factors are fully mediated by the first-order factors leads to a significantly poorer fit to the data than in bifactor models (e.g., Reise, 2012; Gignac, 2016). These observations strongly support the use of bifactor models as the preferred approach for accurately separating the variance in indicators, distinguishing between what can be attributed solely to overarching factors and what is specific to individual constructs (Morin et al., 2020).

In the context of the study of instructional quality, it can be assumed that there is both a hierarchically ordered construct and that the S-factors have a conceptual overlap. In order to account for these features, it is appropriate to integrate a combination of ESEM and bifactor modeling into one model, which has recently become possible through the development of the bifactor ESEM framework (Morin et al., 2020). Thus, it becomes possible to address for potential cross loadings and to investigate the explanatory power of the S-factors as well as the G-factor simultaneously. This aspect holds significant importance because research indicates that neglecting both layers in predictive models, assuming their coexistence, poses the risk of overlooking valuable insights into the distinctive impact of each S-Factor beyond the G-Factor. Neglecting to evaluate global factors within the structural model could lead to an overestimation of the specific factors' influence and result in an incomplete understanding of the general factor (Alamer, 2022).

2 Research questions and hypothesis

We investigate the transferability and adaptation of an extended model of the three basic dimensions as a parsimonious model of instructional quality for PE. In doing so, the theoretical foundations of the previous sections lead us to the following research questions and hypotheses:

1 To what extent does the five-factor model of instructional quality in physical education represent the model to be favored with the best fit to the data? We hypothesize that a latent factor model with five individual- and class-level dimensions will provide the best fit to the data (H1).
2 Given different individual-level modeling approaches, to what extent can the factor structure of instructional quality be described? We assume the B-ESEM to yield the best fit to the data and that the model can give us otherwise inaccessible, valuable evidence about the internal structure of the data (H2).
3 To what extent can substantial cross-loadings on the untargeted factors be identified? We assume that, due to the high inter-factor correlations to be assumed, there are significant cross-loadings of non-targeted factors between cognitive-motor activation, motivational-emotional support and adjusted and blanked cognitive-motor support. However, the highest factor loadings in each case correspond to the target factors (H3).
4 To what extent are the items of classroom management be reflected in the G-factor? Based on theoretical rationales and empirical evidence, we assume that our parsimonious conceptualization of classroom management has considerably smaller factor loadings with respect to the G-factor (H4).

3 Materials and methods

3.1 Procedure and participants

Data stems from the anonymzed study (anonymized authors) has to be adapted in: "EPiC-PE study" and "Messmer et al. (2022)" which aims to investigate the effects of professional competencies of PE teachers on instructional quality and students' outcomes. We focus in particular on the second measurement point, at which instructional quality was surveyed, referring to a 12-lesson teaching series. For the recruitment of

the participants, secondary schools in several German-speaking cantons of Switzerland were contacted. Data collection took place between October 2021 and April 2022. The completion time of the whole survey section took 15–20 min at each measurement point and was complemented by a knowledge test. Beforehand, the students received a short explanation from their teacher, who was trained for this purpose by means of a standardized written explanation. Parents were informed prior that participation was voluntary and were required to sign an informed consent form. Students were also informed that participation was voluntary. No incentives were given for participation. The teachers had to complete their own questionnaire and were present during the entire assessment. The total sample consists of 72 different classes and 1,047 students. The average class size for the sample is 14.5 students per class. The average age of students drawn from grades 9 to 11 is 14.5 years (SD = 1.6). Forty-seven percent of the subjects were female.

3.2 Measures

In the context of the parsimonious modeling approach, the operationalization of instructional quality is based on a hybrid concept that combines generic with subject-specific quality characteristics (e.g., Kyriakides et al., 2018; Praetorius and Charalambous, 2018). Due to the minor adjustments for classroom management (CM) compared to other subjects, as well as the focus of the present study to present a parsimonious instrument, the focus was exclusively on low-level disruption. It is likely that variables of a broader understanding of CM (e.g., transition management and monitoring) would ultimately manifest in low-level disruption in the classroom, which in turn should allow for more effective learning time. Although different specifications could have been made for PE (e.g., safety aspect, use of materials), this parsimonious operationalization allows for easier integration into more complex models (e.g., effectiveness analyses). The items were adapted from the DESI and IGLU study (Bos et al., 2005; Wagner et al., 2009).

Due to the broad existing evidence regarding motivational and emotional processes in PE, an attempt was made to combine as many relevant aspects as possible in a consistent and, as it were, parsimonious scale of motivational-emotional support (MES). Accordingly, the items reflect both autonomy and competence support of the SDT as well as the teacher-student relationship in terms of relatedness. Furthermore, a motivating teaching style, a positive feedback approach, and an individual reference norm orientation were integrated (see section 1.3.2). The items were adapted from the COACTIV, DESI, and IGLU study as well as the General Self-Efficacy Scale (Schwarzer and Jerusalem, 1999; Bos et al., 2005; Baumert et al., 2009; Wagner et al., 2009).

Adjusted cognitive-motor support (ACMS) contains indicators that reflect modeling, explaining and highlighting in the context of augmented feedback. On the one hand, it refers to the correctness of the exercise execution; on the other hand, it explicitly focuses on the identification and correction of errors in movement execution. Therefore, it integrates both informational and corrective feedback. Blanket cognitive-motor support (BCMS) contains items that focus in particular on developmentally sequenced activities as well as the pre-movement emphasis on important movement elements and goals. The focus is on the role of teacher guidance of students in complex learning environments, aiming to reduce complexity as well as clear outline of the objectives of the exercises.

Finally, the dimension of cognitive-motor activation (CMA) includes challenging tasks, exploration of students' movement actions, and metacognitive learning. It is assumed that "prior knowledge" (in PE rather the prerequisite of motor competence) manifests itself in the adequacy of the level of challenge, which is reflected in the items. One difficulty lay in the question of whether higher order thinking, analogous to other subjects, is beneficial to learning success in PE or rather inhibits the automation of movements. Following the generic model of the three basic dimensions, higher-order thinking is integrated into the scale, but the impact is an open question that should be addressed in subsequent studies of prognostic evidence. Items for both dimensions of cognitive-motor support and CMA has been adapted from Herrmann (2019).

4 Analysis

First, we conducted single-level ICM-CFA and MCFA that was specified doubly latent accordingly to the approach of Marsh et al. (2009). We compared the hypothesized five-factor structure with the four-factor structure (ACMS and BCMS represent one dimension) and other alternative models of the common integration of facets of cognitive support into the three basic dimensions (see Section 1.2). After a potentially different factor structure appeared on the different levels, we compared a model with five-factors at the individual-level and four-factors at the class level with the alternative models.

Regarding the ESEM and B-ESEM, the first step of a sequential analysis strategy was presented in the theory section as a rationale for the usefulness of assuming a hierarchically ordered construct that has conceptual overlap in dimensions (Morin et al., 2020). Following Morin et al. (2016), the second step was to compare ICM-CFA and ESEM to test for the presence of construct-relevant psychometric multidimensionality. In this step, ESEM should show a better fit to the data, inter-factor correlations should decrease, and low to moderate cross-loadings should emerge. Larger cross-loadings should be able to be explained well and the factors should be well defined. The third step consists of a comparison of the model to be favored (CFA or ESEM) with a bifactor solution (B-CFA or B-ESEM). An improvement of the model fit as well as a well-defined G-factor can be considered as evaluation criteria. The S-factors should be at least partially well defined, although it is not necessarily considered critical in bifactor models for all S-factors, as these serve as controls of residual specifications shared between a subset of indicators (Morin et al., 2020). ESEM and B-ESEM were conducted with oblique target rotation (Figure 1).

All models were estimated using Mplus 8.7 (Muthén and Muthén, 2017) with robust Maximum Likelihood estimation (MLR), which is robust against non-normality of item responses. Despite the categorical variables, we preferred MLR estimation over weighted least squares means and variance adjusted (WLSMV) estimation, following the practice of Aguado et al. (2015) and Scherer et al. (2016). In this context we specify at least four response options on a frequency scale, we can use the "missing at random" (Asparouhov and Muthén, 2010) handling of missing data, and we follow the recommendation of Marsh et al. (2009) regarding the use of MLR estimation in the application of ESEM. Goodness-of-fit was assessed using the absolute fit indices, adhering to conventional cutoff values from Hu and Bentler (1999): standardized root mean square residual (SRMR) ≤ 0.08; root mean square error of approximation (RMSEA) ≤ 0.06; comparative fit index (CFI) and tucker-lewis index (TLI) ≥ 0.95 as well as χ^2/df-Ratio

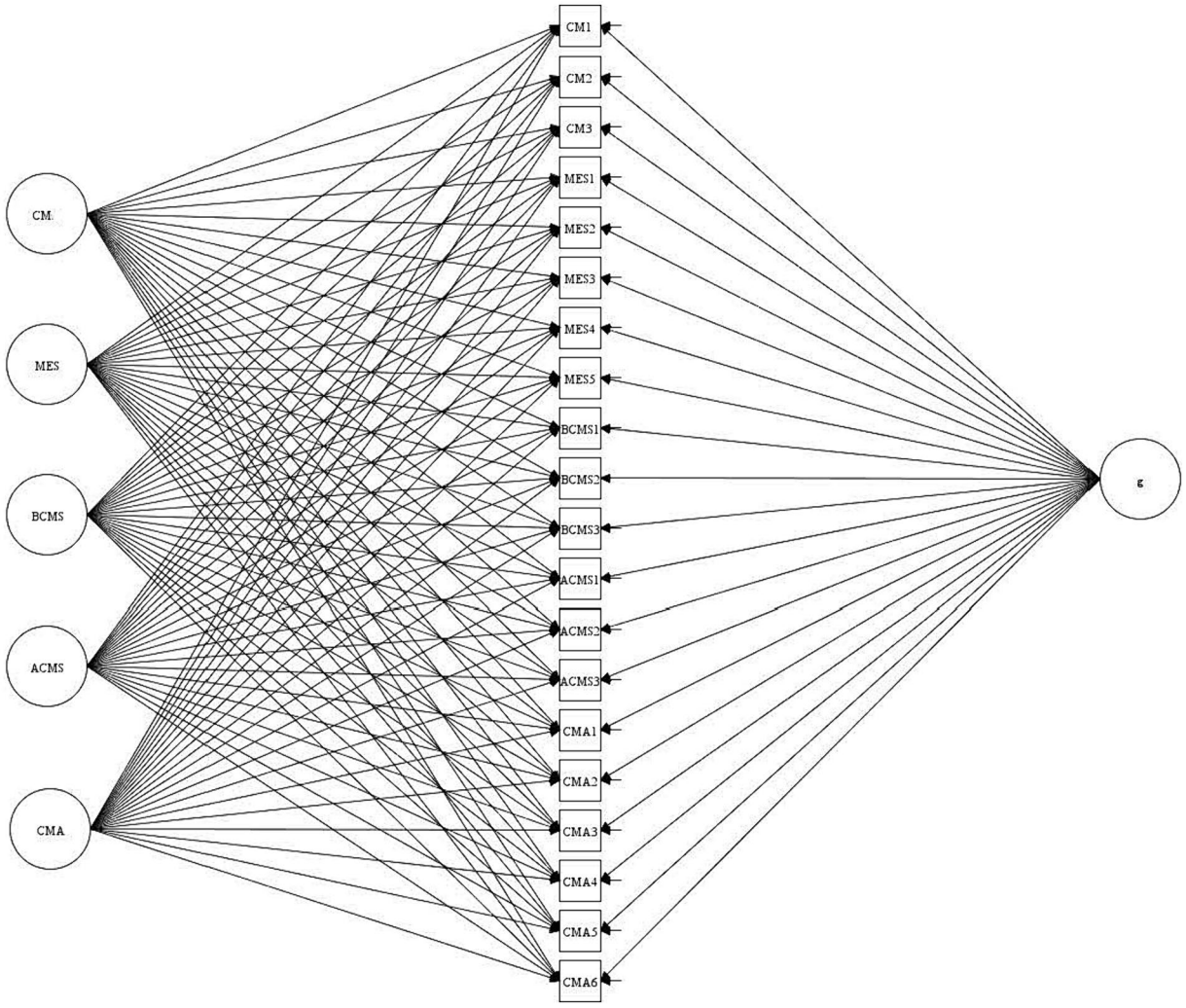

FIGURE 1
B-ESEM solution of the measurement model. CM, Classroom management; MES, Motivational-emotional support; BCMS, Blanket cognitive-motor support; ACMS, Adjusted cognitive-motor support; CMA, Cognitive-motor activation.

(Wheaton et al., 1977). Additionally, lower Akaike Information Criteria (AIC), Bayesian Information Criteria (BIC), and chi-square difference testing using the Satorra-Bentler scaled chi-square indicated favorable models (Morin et al., 2016). The COMPLEX function of Mplus (Asparouhov, 2005) was used for all individual-level models to estimate goodness-of-fit and standard errors robust to the nested data structure. The proportion of missing values per item was between 0.0 and 1.9%. Missing values were addressed using the full information maximum likelihood estimator (FIML).

5 Results

5.1 Descriptives

All Items with descriptives can be found in the Appendix. Intraclass correlation coefficients (ICCs) as well as design effects indicated substantial dependence of clustering of the data within classes. In this context, ICC1 values higher than 0.05 indicate meaningful correlations of variables between and within. ICC2 values higher than 0.60 indicate a meaningful aggregation of the individual-level data on the class level (Bliese, 2000; Chen et al., 2005). Only CMA showed ICC1 values that were only slightly above the cut-off of 0.05. The ICC2 values were below 0.60 and also the design effects were below 2.0. Accordingly, the reliability of the scale at the class level can be described as insufficient. Table 1 shows an overview of the descriptives.

5.2 Results of the ICM-CFA

To address Research Question 1, we first examined the different alternative models at the individual level using ICM-CFA. We examined the extent to which a unidimensional factor had an acceptable model fit, assuming that we were measuring the superior construct of instructional quality. This model had a poor model fit (Table 2) and was therefore rejected. The next step was to examine the possible alternative models that integrated cognitive-motor support within the other basic dimensions. Integration into CM was not considered because the parsimonious operationalization did not suggest a meaningful integration in terms of content. The integration into CMA showed a poor model fit, whereas the integration into MES showed an acceptable, if not good model fit. Next, the four-factor model of an

TABLE 1 Descriptives of instructional quality dimensions.

Factor	Items	Item example (1 = not true at all; 4 = exactly true) ("In our physical education class…"; "Our physical education teacher…").	*M*	*SD*	α	ω	ICC1	ICC2
Classroom management	3	There are many disruptions by students. (*r*)	2.84	0.72	0.84	0.84	0.15–0.21	≥0.70
Motivational-emotional support	5	Often makes physical education lessons really exciting.	3.02	0.64	0.81	0.81	0.12–0.18	≥0.66
Blanket cognitive-motor support	3	Gradually introduces the exercises step by step.	3.21	0.63	0.82	0.82	0.13–0.14	≥0.67
Adjusted cognitive-motor support	3	Shows us errors in the execution of exercises.	3.23	0.62	0.86	0.86	0.13–0.15	≥0.68
Cognitive-motor activation	6	Makes me think about how I should execute the exercises.	2.82	0.63	0.87	0.87	0.06–0.08	≥0.47

integrative dimension of BCMS and ACMS was tested. This solution resulted in a significantly better model fit compared to the alternative models. Finally, the postulated five-factor model was tested, in which BCMS and ACMS represent independent dimensions. The model shows a significant improvement of the model fit with respect to the Satorra-Bentler Scaled Chi-Square difference test. RMSEA, CFI, and TLI each improved by 0.01, whereas SRMR remained the same. AIC and BIC also indicate a preference for the five-factor solution. In summary, the five-factor model represents the model to be favored, following common cut-off values of model comparison (Table 2).

5.3 Results of the MCFA

In a next step, the factor structure was tested simultaneously at individual and class level using MCFA (Table 3). The procedure as well as the results regarding the unidimensional model and the integration into the three-factor solutions on individual and class level are largely congruent with the ICM-CFA. However, when comparing the four- and five-factor solution, no improvement in the SRMR between could be demonstrated, while the fit indices at the individual level indicated a better fit to the data. Accordingly, Model 1b was specified, which tests a five-factor structure at the individual level and a differential four-factor structure at the class level. Model 1b did not show a worse model fit and even showed better values for the AIC and BIC than Model 1a. In addition, there was an almost perfect inter-factor correlation at the class level between BCMS and ACMS (see Table 4). Table 5 presents the inter-factor correlations at the class level with respect to the four-factor solution, with the two highest inter-factor correlation at 0.91 in a common range for the class level. The overall correlational pattern is in line with expectations, being higher between conceptual closer dimensions at both levels. The different factor structure on the two levels is not unusual in the context of MCFA, as multilevel models often tend to show a simpler factor structure at the class level compared to the individual level (Dedrick and Greenbaum, 2011). All factor loadings were found to be statistically significant. On the student level, standardized loadings for all items ranged from 0.47 to 0.81, while on the class level, the range was from 0.59 to 1.00.

5.4 Results of the ESEM and B-ESEM

To address research questions 2, 3, and 4 in a next step, we specified an ESEM and B-ESEM solution. The sequential procedure first consisted of testing the presence of construct-relevant psychometric multidimensionality using ESEM. As Table 6 shows, the ESEM solution had an excellent model fit and outperformed the ICM-CFA (ΔCFI = +0.02, ΔTLI = +0.02, ΔSRMR = −0.03, AIC, BIC). Furthermore, the inter-factor correlations decreased substantially (Table 7). As for the MCFA, the correlational pattern is in line with expectations, being higher between conceptual closer dimensions. Also in line with expectations are the low inter-factor correlations with CM, which already serves as an indication with regard to research question 4.

Regarding the ESEM factor loadings (Table 7), target loadings above 0.50 are considered completely satisfactory following Morin et al. (2020). Target loadings below 0.30 question the adequacy of the indicator. The target loadings of the ESEM solution are in an acceptable range except for item CM6 (0.29), and even in a completely satisfactory range except for item BCMS2 (0.48). All cross loadings are in a negligible range (<0.40), whereby individual attention should be paid to both the justifiability of the content and the relative height to the target loading. In principle, it should be noted that cross-loadings only reflect the construct-relevant association between an indicator and a non-target factor, so that higher cross-loadings may be tolerated if they make theoretical sense (Morin et al., 2020). In line with expectations, cross-loadings worth mentioning occur for item CM6 as well as for the theoretical aligned BCMS and ACMS items. Importantly, these cross-loadings may suggest that an unmodelled G-factor might be present (Morin et al., 2020). Furthermore, since ESEM is supported by the improvement of the model fit, the reduced inter-factor correlations, low to moderate cross-loadings and well-defined target factors, a B-ESEM solution was specified in a next step.

Regarding research question 2, Table 6 shows that the B-ESEM solution had an even better model fit than the ESEM solution (e.g., ΔCFI = +0.01, ΔTLI = +0.01, ΔRMSEA = −0.02). Furthermore, the B-ESEM solution shows a well-defined G-factor and resulted in a non-significant chi square value ($p = 0.12$), suggesting that it is the only model with exact model fit to the data. However, as we assumed for research question 4, items assigned to CM showed only small loadings on the G-factor (λ = 0.09–0.13), but high loadings on the S-factor (λ = 0.73–0.81). The other target factors can also be described as predominantly well defined. With regard to research question 3, the highest factor loadings in each case correspond to the target factors. Interestingly, item CM6 also has significant loadings on the G-factor and the S-factor. The cross-loadings observed in the ESEM thus appear to be mainly explained by the shared G-factor.

6 Discussion

The main goal of the present study was to transfer and extend a popular model of generic research on instructional quality to PE. As part

TABLE 2 Fit statistics of ICM-CFA measurement models.

Model	Specifics	χ^2	df	χ^2/df	RMSEA	CFI	TLI	SRMR	AIC	BIC	ΔCFI	ΔRMSEA	TRd	Δdf	*p*
1	CM, MES, ACMS, BCMS, CMA	371.89**	160	**2.32**	**0.03**	**0.97**	**0.97**	**0.04**	**38,506**	**38,853**					
2	CM, MES, CMS, CMA	440.76**	164	2.69	0.04	0.96	0.96	**0.04**	38,595	38,922	0.01	0.01	59.11	4	0.00
3	CM, MES, CMA+ CMS	728.70**	167	4.36	0.06	0.93	0.92	0.05	38,986	39,297	0.04	0.03	306.9	7	0.00
4	CM, MES + CMS, CMA	1433.10**	167	8.58	0.09	0.84	0.82	0.07	39,932	40,245	0.13	0.06	1103.28	7	0.00
5	General	2609.73**	170	15.35	0.12	0.7	0.66	0.10	41,464	41,761	0.27	0.09	2299.58	10	0.00

CM, Classroom management; MES, Motivational-emotional support; CMS, Cognitive motor support (compound); ACMS, Adjusted cognitive motor support; BCMS, Blanket cognitive motor support; CMA, Cognitive motor activation; $^{**}p < 0.01$. Bold values indicate the best model fit.

TABLE 3 Fit statistics of the MCFA.

Model	Specifics	χ^2	df	χ^2/df	RMSEA	CFI	TLI	SRMR within	SRMR between	AIC	BIC	ΔCFI	ΔRMSEA	TRd	Δdf	*p*
1a (5/5)*	CM, MES, ACMS, BCMS, CMA	756.20**	335	2.26	**0.03**	**0.96**	**0.96**	**0.04**	**0.10**	38,136	38,656					
1b (5/4)*	Individual: CM, MES, ACMS, BCMS, CMA Class: CM, MES, CMS, CMA	754.41**	339	**2.23**	**0.03**	**0.96**	**0.96**	**0.04**	**0.10**	**36,185**	**36,666**	0	0	0.63	4	0.96
2 (4/4)*	CM, MES, CMS, CMA	854.86**	344	2.49	0.04	0.95	0.95	**0.05**	**0.10**	38,215	38,691	0.01	0.01	75	9	0.00
3 (3/3)*	CM, MES, CMA + S	1270.91**	351	3.62	0.05	0.91	0.90	0.05	0.12	38,592	39,033	0.05	0.01	364	17	0.00
4 (3/3)*	CM, MES + CMS, CMA	2300.67**	351	6.55	0.07	0.81	0.79	0.07	0.19	39,530	39,970	0.16	0.04	1,142	16	0.00
5 (1/1)*	General	3791.53**	359	10.56	0.10	0.66	0.65	0.10	0.25	40,915	41,316	0.3	0.06	2,454	24	0.00

CM, Classroom management; MES, Motivational-emotional support; CMS, Cognitive motor support (compound); ACMS, Adjusted cognitive motor support; BCMS, Blanket cognitive motor support; CMA, Cognitive motor activation; *Number of factors at individual/class level; $^{**}p < 0.01$.

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of a multi-step procedure, the factor structure was examined. Further studies are indicated in the future for in-depth analysis on prognostic validity and prerequisites like teacher's professional competencies or continuing professional development (Tannehill et al., 2021; Büchel et al., 2023). Various subject-specific adaptations and additions were made and grounded against the background of substantial theoretical and empirical evidence. ICM-CFA and MCFA were applied to examine the factorial structure of instructional quality in PE. Within the ICM-CFA, it could be shown that the postulated model with five factors showed both a good model fit and the best model fit in comparison to the alternative models. Regarding the MCFA, the ICC1 and ICC2 values were first calculated as a measure of the degree of dependency of the data within classes. The ICC1 values of CMA were found to be rather low, whereas CM showed the highest values. MES, BCMS, and ACMS had similar ICC1 and ICC2 values. These findings are largely in line with expectations and can be justified on the basis of the degree of inference (e.g., Wisniewski et al., 2020). The low ICC1 values for CMA tend to be at the lower end of the values reported in studies of other subjects (e.g., Fauth et al., 2014; Wisniewski et al., 2020). One possible explanation for the lower ICC1 values of the CMA could lie in the item reference on the individual student, whereas the other factors are more strongly aimed at general teaching or the teacher (Fauth et al., 2020). Accordingly, the differences in the ICC1 values could be explained less by the construct but rather by the item reference. Therefore, consideration of the item reference seems to be a worthwhile investigation in further studies. Previous research has found different combinations of item references between and within constructs, which appear to be associated with the ICC1 values (Holzberger et al., 2013; Fauth et al., 2014). This differentiated psychometric consideration, which is relatively new in research on instructional quality, is also a potentially important approach for explaining inconsistent findings with regard to the predictive validity of students' perceptions as well as with regard to the low level of agreement with other data sources such as external observations. With the exception of CMA (≥0.47), the ICC2 values showed satisfactory reliability of the aggregated class mean values. For the focus of the analysis at class level, a careful adjustment of CMA appears to be indicated.

With regard to the inter-factor correlations, the results are largely consistent with other studies (Kane et al., 2014; Röhl and Rollett, 2021). Accordingly, with the exception of CM, high inter-factor correlations can be reported between the dimensions at both individual and class level. With regard to CM, it is advisable to take a closer look at the specific operationalization. In studies that have operationalized CM in a broader sense or with a focus on other facets (e.g., Wagner et al., 2013; Wisniewski et al., 2020), higher inter-factor correlations can be observed, whereas studies with a focus on low-disruptive behavior tend to report similar findings (e.g., Fauth et al., 2014; Kleickmann et al., 2020). No significant inter-factor correlation was found between CM and cognitive-motor activation at class level either, whereas substantial inter-factor correlations were found between CM with cognitive-motor support and MES (Table 5). Finally, MES in particular shows high inter-factor correlations. The question of the influence of an affective overall attitude in the sense of perceived "communion" can be cited here in particular as a question and at the same time as a possible explanation (Kuhfeld, 2016; Wallace et al., 2016; Röhl and Rollett, 2021).

While the postulated model with five factors for the individual level showed the best model fit, a less differentiated factor structure was evident at the class level. Against this background, no improvement in the model fit resulted by differentiating the two components of cognitive-motor support, AIC, and BIC even pointed out the preference for the four-factor model. In contrast, a structure with four factors at the individual level showed a poorer model fit (ΔCFI = −0.01, ΔRMSEA = +0.01, AIC, BIC). Therefore, as a result of model fit, theoretical stringency in terms of the conceptually adjacent dimensions and the principle of parsimony, Model 1b represented the adopted model. From a theoretical point of view, no different interpretation was postulated at the two levels of analysis, although a simpler factor structure at the higher level can be described as a common phenomenon (e.g., Dedrick and Greenbaum, 2011). Nevertheless, it could also be shown for the class level that an extension of the model of the three basic dimensions for PE by a

TABLE 4 Inter-factor correlations of the five-factor solution at both levels.

Factor	CM	MES	BCMS	ACMS	CMA
CM	1	0.07	0.05	0.01	0.05
MES	0.43**	1	0.77**	0.71**	0.59**
BCMS	0.53**	0.93**	1	**0.87****	0.60**
ACMS	0.51**	0.90**	**0.998****	1	0.60**
CMA	0.05	0.88**	0.67**	0.64**	1

Inter-factor correlations at individual level above the diagonal; class level below the diagonal; highest expected inter-factor correlations in bold; decision-supporting values of the undifferentiated factor structure at class level are underlined; **$p < 0.01$.

TABLE 5 Inter-factor correlations of the four-factor solution at class level.

FaCtor	CM	MES	CMS	CMA
CM	1			
MES	0.43**	1		
CMS	0.52**	0.91**	1	
CMA	0.05	0.88**	0.65**	1

**$p < 0.01$.

TABLE 6 Comparison of the fit statistics of the ICM-CFA, ESEM, and B-ESEM.

Model	Specifics	χ^2	df	χ^2/df	RMSEA	CFI	TLI	SRMR	AIC	BIC	ΔCFI	ΔRMSEA	TRd	Δdf	*p*
1	B-ESEM	100.88	85	**1.19**	**0.01**	**1**	**1**	**0.01**	**38,282**	**38,540**					
2	ESEM	163.76**	100	1.64	0.03	0.99	0.99	**0.01**	38,347	38,578	0.01	0.02	52.31	15	0.00
3	ICM-CFA	371.89**	160	2.32	0.03	0.97	0.97	0.04	38,506	38,630	0.03	0.02	263.5	75	0.00

**$p < 0.01$.

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TABLE 7 Factor loadings of the three measurement approaches and inter-factor correlations of ICM-CFA and ESEM solution.

Items	CFA	ESEM					Bifactor ESEM					
		CM	MES	BCMS	ACMS	CMA		CM	MES	BCMS	ACMS	CMA
	β	β	β	β	β	β	G-β	S-β	S-β	S-β	S-β	S-β
CM1	**0.82****	**0.82****					**0.10***	**0.81****				
CM2	**0.82****	**0.82****					**0.11****	**0.81****				
CM3	**0.75****	**0.74****					**0.16****	**0.73****				
MES1	**0.72****		**0.64****			0.12**	**0.61****		**0.35****			0.10**
MES2	**0.72****		**0.83****	−0.11*			**0.58****		**0.50****			
MES3	**0.77****		**0.90****				**0.63****		**0.51****			
MES4	**0.68****		**0.58****				**0.60****		**0.30****			
MES5	**0.67****		**0.38****	0.16*		0.16**	**0.62****		**0.18****			0.10*
BCMS1	**0.77****		0.10*	**0.66****			**0.77****			**0.19****		
BCMS2	**0.79****		0.10**	**0.48****	0.29**		**0.74****			**0.19****	0.13**	−0.10**
BCMS3	**0.78****			**0.58****	0.12	0.12**	**0.76****			**0.20****		
ACMS1	**0.83****			0.34**	**0.52****		**0.78****				**0.24****	
ACMS2	**0.79****			−0.14*	**0.91****		**0.68****				**0.52****	
ACMS3	**0.84****			0.14*	**0.66****		**0.74****				**0.36****	
CMA1	**0.74****					**0.77****	**0.49****			−0.21*		**0.57****
CMA 2	**0.77****					**0.76****	**0.55****			−0.27*		**0.56****
CMA 3	**0.80****					**0.82****	**0.50****			0.13*		**0.63****
CMA 4	**0.78****				0.11	**0.73****	**0.50****			0.16**	0.12**	**0.60****
CMA 5	**0.79****					**0.81****	**0.49****			0.11*		**0.62****
CMA 6	**0.48****		0.19**	0.24**	−0.10	**0.29****	**0.50****				−0.11*	**0.18****

	Inter-factor correlations for ICM-CFA (above the diagonal) and ESEM (below the diagonal)				
Factor	CM	MES	BCMS	ACMS	CMA
CM	1	0.09	0.06	0.01	0.04
MES	0.16**	1	0.76**	0.70**	0.60**
BCMS	0.11*	0.69**	1	**0.87****	0.62**
ACMS	0.13**	0.67**	**0.72****	1	0.62**
CMA	0.04	0.58**	0.51**	0.52**	1

Target loadings are in bold; loadings below 0.1 are not shown; highest expected inter-factor correlations in bold; *$p < 0.05$; **$p < 0.01$.

cognitive-motor support dimension represents a theoretically as well as empirically meaningful addition.

In a further step, the individual level was examined using more complex methodological techniques (ESEM, B-ESEM). Overall, it was shown that all three modeling approaches (ICM-CFA, MCFA, ESEM, and B-ESEM) exhibited a good model fit, with the more complex modeling approaches outperforming the ICM-CFA. Basically, the findings show that the students' perception is able to distinguish between the different factors of instructional quality for PE. The findings of the ESEM show significant cross-loadings, which reflect the conceptual overlap of the constructs. In the context of arguments for convergent and discriminant validity, it should first be emphasized that the cross-loadings emerge in line with expectations between theoretically more strongly associated constructs. In particular, significant cross-loadings of the BCMS and ACMS items appear. Regarding research question 3, the target loadings consistently represent the highest factor loadings and the factors can be described as well defined. Only item CM6 has a target loading <0.30 and higher cross-loadings. The item wording ("Our PE teacher gives us different exercise tasks, depending on our ability") does indeed differ from the other items, which focus more on higher-order thinking, exploration of students' movement actions, and metacognitive learning (see Appendix). Even if the assignment to CMA can be justified within the framework of the generic model of the three basic dimensions,

we consider the connection to motivational and emotional processes as well as to ACMS and BCMS in the sense of cognitive load to be just as viable, which is congruent with the notion of the connection between the student-teacher relationship and feedback in PE (Zhou et al., 2021). As expected, the inter-factor correlations of the ESEM solution are lower than those of the ICM-CFA, with the exception of CM. This can be considered particularly significant if the latent variables are to be used for predictions, as in this case in further studies, and unnecessary multicoloniality would be introduced (Asparouhov et al., 2015; Howard et al., 2016). In the context of research on instructional quality, this can be considered problematic due to the conceptual overlap and the correspondingly high inter-factor correlations.

With regard to the B-ESEM, CM with low factor loadings on the G-factor was particularly striking. This was expected both in the context of the lower inter-factor correlations of CM with the other factors, but especially in the context of initial evidence regarding B-ESEM in the context of the three basic dimensions (Scherer et al., 2016). In this context, the inter-factor correlations of all modeling approaches underline the assumption of conceptual closeness of the other dimensions compared to CM, showing that stronger inter-factor correlations occur between conceptually adjacent factors and lower inter-factor correlations between conceptually distal factors. Otherwise, the G-factor is well defined for all other dimensions and supports the assumption of the presence of a superordinate factor. The loadings on the S-factors all show significant target loadings, indicating that they can explain variance beyond the G-factor.

Overall, the findings of our study provide strong support for the factorial structure of the measurement model in question. In this context, a foundation of instructional quality from a hybrid perspective, which integrates generic and subject-specific approaches, appears to be a promising direction. Assuming conceptually overlapping dimensions and a general factor of instructional quality, we were able to use the more complex modeling approaches (ESEM, B-ESEM) to address both the cross-loadings among items and factors and to disentangle the variance explained by the general factor and the specific factors. This seems particularly important in light of current challenges in research on instructional quality, as problems regarding factor mean differences and the relationship to other constructs can be addressed.

Nevertheless, different limitations of the measurement model can be identified. First, certain aspects could not be integrated. Especially, transferring evidence on focus of attention into the instrument can be understood as potentially important. Furthermore, in the context of the study's focus on a parsimonious model, we had to make further limitations, such as the focus on disruptive behavior or verbal feedback, as the most common source of augmented feedback in PE. Second, it should be emphasized that there is an ongoing debate about the extent to which laboratory studies of motor learning can be transferred to everyday settings (e.g., Wolpert et al., 2011). Third, according to the literature on motor learning as well as models of PE, there may be contradictions where it cannot be conclusively assessed in which context which approach would be beneficial. For example, the discovery-based learning (DBL) model and high structuring of lessons are opposed to each other. Likewise, the methodological series of exercise model or the methodical games series model are not necessarily compatible with DBL. Against this background, it should be emphasized that different approaches should certainly be evaluated against the background of the objective of individual lessons. The measurement model presented can therefore only be understood in the context of overarching quality dimensions by reducing the complexity of teaching. Fourth, the greatest limitation is certainly the current lack of evidence regarding further arguments of validity like the effects on significant educational outcomes, which has to be addressed in further studies. The present study can therefore be seen as a first step, in the sense of a multi-step procedure, for arguments regarding the factorial validity of the instrument.

Data availability statement

The datasets presented in this article are not readily available because there is a data embargo until the completion of dissertations associated with the project by January 31, 2025. Requests to access the datasets should be directed to felix.kruse@phsg.ch.

Ethics statement

Ethical approval was not required for the studies involving humans because in accordance with national guidelines in connection with the collection of non-sensitive data, no ethics vote was required for the study. The active consent of the parents was obtained before the study was conducted. 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

FK: Formal analysis, Writing – review & editing, Writing – original draft. SB: Conceptualization, Writing – review & editing. CB: Conceptualization, 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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Appendix

item	Item formulation ("In our physical education class..."; "Our physical education teacher...").	*M*	*SD*	*rit*	*ICC1*
Classroom management	often has to wait a long time until it is quiet. (r)	2.79	0.82	0.69	0.21
	there are many disruptions by students. (r)	2.74	0.82	0.69	0.21
	things are often chaotic. (r)	2.95	0.81	0.65	0.15
Motivational-emotional support	often makes physical education lessons really exciting.	2.95	0.83	0.65	0.15
	takes care of the students' problems.	3.14	0.84	0.64	0.17
	tries to fulfill the wishes of the students as far as possible.	3.07	0.83	0.71	0.18
	praises students in particular when they have improved on their previous performance.	3.14	0.80	0.62	0.13
	it is recognized when I achieve something	3.00	0.78	0.58	0.12
Blanket cognitive-motor support	gradually introduces the exercises step by step.	3.19	0.76	0.68	0.14
	points out the important aspects of the exercises.	3.29	0.71	0.69	0.13
	makes the objectives of the exercises clear.	3.21	0.76	0.69	0.14
Adjusted cognitive-motor support	points out the correct execution of exercises.	3.25	0.68	0.72	0.14
	points out errors in the execution of exercises.	3.21	0.73	0.76	0.13
	gives us advice on how to improve exercise execution.	3.22	0.73	0.77	0.15
Cognitive-motor activation	encourages me to think through the exercises after performing them.	2.83	0.84	0.72	0.06
	encourages me to think about how well I did the exercises.	2.89	0.84	0.77	0.07
	encourages me to think about how I could learn new exercises.	2.81	0.83	0.76	0.06
	makes me think about how I should execute the exercises.	2.94	0.79	0.73	0.06
	makes me think about the benefits of the exercises for me.	2.88	0.82	0.74	0.08
	gives us different exercise tasks, depending on our ability.	2.61	0.93	0.50	0.08

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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Pierluigi Diotaiuti,
University of Cassino, Italy
Jose Antonio López-Pina,
University of Murcia, Spain

*CORRESPONDENCE
Getabirhan Getinet Melesse
✉ getabirhangetinet@gmail.com

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Validation of the basic need satisfaction for sport scale in Ethiopian athletes

Getabirhan Getinet Melesse[1]*, Zelalem Melkamu Tegegne[1] and Sangeeta Rani[2]

[1]Sport Science Department, Sport Academy, Bahir Dar University, Bahir Dar, Ethiopia, [2]Maa Omwati College of Education, University/College-MOIEC, Palwal, India

By anchoring on the self-determination theory in an Ethiopian context, this study tried to establish the basic need satisfaction sport scales (BNSSS) reliability and validity. Despite the scale's usefulness in measuring athletes' psychological need fulfillment during a sporting event, no study has proven the scale's validity in a setting of Ethiopian sports. To validate the BNSSS scale, confirmatory factor analysis was used in the study. The 20 items of the BNSSS questionnaire's English translation are divided into five categories: relatedness, competence, autonomy-perceived locus of internal causality, autonomy-choice, and volition. Senior language experts translated the BNSSS questionnaire into Amharic. The Amharic version of the instrument was used to gather data from 321 athletes, 174 men, and 147 women, with a mean age of 23.34 22.59 and a standard deviation of 5.08 and mean age 5.32; a standard deviation of 2.33 year of experience in their sports from four baseball games. With a Cronbach's alpha value ranging from 0.848 to 0.882 (IPLOC to Volition respectively) across the five subscales and, the results confirm the reliability of the BNSSS for evaluating satisfaction with basic needs and motivation among Ethiopian athletes." The result demonstrated an acceptable fit with the data (CFI, = 0.958, GFI, = 0.933, RMR, = 0.76, RMSEA, = 0.39) as well as internal consistency. All of the components' Cronbach's alpha values met expectations. The instrument's Amharic translation was thus valid and reliable for determining the extent to which Ethiopian athletes' basic needs were met.

KEYWORDS

internal consistency, psychological needs, reliability, self-determination theory, validity

Introduction

A growing body of research studies has recognized basic psychological needs as the key factors that determine and sustain the optimum performance of athletes (1–3). These studies indicated that athletes' sports performance depends on many variables. Almagro et al. (4) indicated that among the influential variables affect sports performance include the three basic psychological needs whose satisfaction affects their motivation to perform better, continue participating in sports activities, and win the competition.

A self-determination perspective contends that variations in motivational levels rely on whether or not athletes are able to satisfy their demands in terms of the three basic psychological requirements (4). Because athletes need to feel engaged and motivated as members of the team, it is crucial to understand how they see their performance (5). In other words, along a linear continuum athletes' motivation levels increase as they gain an increasing degree of satisfaction with their three basic requirements (2). The

more the three basic psychological demands are met by athletes, the more their athletic performance will increase (2).

Self-determination theory is an empirical macro theory of human motivation, psychological growth, and well-being (6). It can be used to explore social circumstances that support or deprive individuals of various sorts of motivation and fundamental psychological needs. According to this theoretical perspective, there are intrinsic and extrinsic motivated behaviors which are driven by the fulfillment of fundamental human needs such autonomy, competence, and relatedness (6). In recent studies examining how different levels of basic psychological needs affect the different types of motivation in the context of athletic sports performance is becoming more and more popular (7, 8). Basic psychological needs have been identified as the primary determinants of and maintainers of the peak athletic performance (1, 2). These studies found that various variables affect an athlete's sporting performance. According to (2), among the key factors that influence sports performance are the three basic psychological demands. In other words, personal fulfillment influences drive athletes to perform better, continue participating in sports activities and win the competition.

A self-determination perspective argues that competence, autonomy, and relatedness are the three essential psychological requirements (7) that an athlete must meet in order to perform well in sports. The degree to which athletes need social situations that encourage autonomy, competence, and relatedness may differ by culture despite the assumption that all people have the same fundamental psychological demands (9). For instance, the level of motivation emphasized by a coach of a regional national league football team may differ from another coach of the national football club. For a person to develop psychologically to its full potential, the basic psychological needs must be met (7).

Several studies have investigated the concept of basic psychological needs. For instance, Brien et al. (10) developed the Basic Psychological Needs at Work Scale (BPNWS), while Vlachopoulos and Michailidou (11) created the Basic Psychological Needs in Exercise Scale. The latter scale consists of 12 items divided into three constructs: competence, autonomy, and relatedness, with four items for each.

The BPNWS demonstrated good internal consistency, with Cronbach's alpha coefficients of 0.81 for competence, 0.84 for autonomy, and 0.92 for relatedness. The model also exhibited a good fit. Similarly Wilson et al. (12) developed a Psychological Need Satisfaction in Exercise Scale consisting of 18 items (six per dimension). This scale also showed high internal consistency, with Cronbach's alpha values of 0.91 for competence and autonomy, and 0.90 for relatedness. The model fit indices for this scale were also satisfactory.

Unlike the previously mentioned scales, which primarily focused on the health benefits of physical activity, Gillet et al. (13) developed the Echelle de satisfaction des besoins psychologiques to assess psychological needs in both physical exercise participants and athletes. This scale comprised 15 items, five for each need, and used a 7-point Likert scale ranging from "not true at all" to "very true." The scale demonstrated acceptable internal consistency, with Cronbach's alpha values of 0.70 for competence, 0.82 for autonomy, and 0.81 for relatedness. Additionally, the model fit indices, CFI and IFI, were both excellent at 0.95, and RMSEA was acceptable at 0.06.

"While the previously mentioned scales demonstrated good reliability and validity in measurements, they did not specifically assess the satisfaction of basic psychological needs in elite athletes' sports. Ng et al. (14) introduced a tool specifically designed to address this gap for measuring basic need satisfaction in competitive sporting contexts. This tool, called The Basic Need Satisfaction in Sport Scale (BNSSS), consists of 20 items: five for competence, five for relatedness, and ten for autonomy (divided into three dimensions: autonomy-choice (four items), autonomy-volition (three items), and autonomy-internal perceived locus of causality (IPLOC) (three items)). Ng et al. (14) applied the BNSSS to a sample of affiliated athletes. The internal consistency of the BNSSS yielded Cronbach's alpha coefficients of 0.77 for competence, 0.82 for autonomy-choice, 0.61 for autonomy-volition, 0.76 for autonomy IPLOC, and 0.87 for relatedness. The model fit indicators also showed favourable results: NNFI = 0.96, CFI = 0.97, RMSEA = 0.06, and standardized root mean square residual (SRMR) = 0.07."

The exceptional performance of Ethiopian distance runners is often attributed to a combination of factors including genetic makeup, early exposure to running, physiological adaptations to altitude, diet, and strong economic motivation. These athletes have dominated middle and long-distance events Wilber et al. (15). While these factors have been well-studied and contribute to success in athletics, their relevance to other sports, such as ball games, is less clear due to a scarcity of research in our specific cultural and geographical context. To bridge this knowledge gap and understand the potential of Ethiopian athletes in different sports, it is crucial to explore factors like basic psychological needs, which have been relatively unexplored in this context (15).

It is observed the lack of questionnaire translated and validated to Ethiopian (Amharic language) to useful with Ethiopian athletes. In this sense, the BNSSS has been an adequate instrument to evaluate athlete's psychological needs in sports setting, however it has not been translated and validated in Ethiopian athletes. So the main aim of this present study was to translate and validate the BNSSS in to Amharic (an Ethiopian language) through adequate translation guide lines, to examine the factor structure, translation and adaptation of the original instrument, an invariance analysis, composite reliability, average variance extracted and to assess the reliability through internal consistency.

Research methods

Participants

The sample comprised of 321 athletes from various team sports, ($n = 174$, 54.21% males, and $n = 147$, 45.79% females) selected through purposive sampling from different sports federations within Ethiopia. Participants in the study ranged in age from 18 to 32 (M: 22.59; SD: 3.29). All of the athletes who took part in this study were members of their respective sport federations and had

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been actively participating in their chosen sport for at least two years on average (M = 5.32 years, SD = 2.33) and range of 2–12 years of experience. The participants' demographic charactristics stated in Table 1. During the permission process, the participants were informed of the purpose of the study and their ethical rights; their responses are held in confidence. The correlation between the five BNSSS construct has been studied as shown in Table 2. Strong correlation has shown between internal perceived locus of causality and relatedness 0.631** and weak correlation observed between competence and relatedness 0.108*.

Basic need satisfaction sport scale (BNSSS)

The basic psychological need satisfaction of individuals is assessed by Basic Psychological Needs Satisfaction Sport Scale (BNSSS) instrument, developed by (14). It was the one of preferred measurement sport specific tool which showed valid psychometric properties (16). The BNSSS comprises of 20 measures that fall into five categories of: relatedness, competence, autonomy choice, autonomy volition, and autonomy (IPLOC) internal perceived locus of causality. The BNSSS is an inclusive instrument that uses a seven-point likert-type answer scale with responses ranging from 1 ("not true at all") to 7 ("very true") higher scores represent greater psychological need fulfillment. Ng et al. (14) demonstrated that BNSSS have adequate internal consistency scores alpha coefficient of: 0.77 for competence; 0.82 for autonomy-choice; 0.76 for autonomy-IPLOC; 0.61 for autonomy-volition, and 0.77 for relatedness constructs. The current study also yielded adequate internal consistency Table 3 scores for competence ($\alpha = 0.88$), autonomy-choice ($\alpha = 0.879$), autonomy-IPLOC ($\alpha = 0.85$), autonomy-volition ($\alpha = 0.882$), relatedness ($\alpha = 0.869$) and Cornbrash's alpha of 20 item BNSSS is 0.858 while Mc Donalds Omega value of 20 items BNSSS is 0.868 see Table 4. The current study also calculated its average variance extracted and composite reliability for each sbscales for assuring adequate discriminant and convergent validity can be viewed in Table 3. The BNSSS has a good factor structure of (CFI = 0.958; RMSEA = 0.053), indicating that the instruments validity is good. As a result, the present translation of BNSSS into Amharic study examined the reliability and validity of the Amharic translation using internal consistence and construct validity to ensure that it can be used to measure Ethiopian athletes satisfaction with their basic needs.

Instrumentation

Ethiopian athletes took part in the study. Participants' responses were gathered using an Amharic version of the recent version of the Basic Psychological Need Satisfaction for Sport Scale (BPNSS) Questionnaire. The basic psychological needs satisfaction for sport scale surveys with 20 items was completed by the participants. The 20 questions that made up this sport scale are divided into five subscales. This study established the validity and reliability of the Amharic (an Ethiopian language) translation and validation of the basic psychological needs

TABLE 1 Demographic characteristics.

Sport type	Gender		T	MM_{age}	MSD_{age}	MM_{exp}	MSD_{exp}	WM_{age}	WSD_{age}	WM_{exp}	WSD_{exp}	TM_{age}	TSD_{age}	TM_{exp}	TSD_{exp}
	M	W													
FB	59	54	113	21.4	3.05	4.9	1.96	20.7	2.35	3.94	1.83	22.7	2.34	3.94	1.82
VB	46	38	84	24.4	2.75	6.09	2.15	23.76	2.98	6.03	2.33	24.08	2.85	6.06	1.02
BB	36	29	65	22.7	3.44	5.08	2.23	22.41	2.45	5.55	2.16	22.57	3.02	5.29	2.19
HB	33	26	59	25.3	3.86	7.24	2.64	20.85	1.89	4.04	1.18	23.36	3.85	5.83	2.65
Men			174	23.2	3.5	5.72	2.4								
Women			147					21.9	2.8	4.8	2.2				
Total	174	147	321									22.6	3.3	5.3	2.3

MM_{age}, Men mean age; SD, standard deviation; exp, experience; T, total; W, women.

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TABLE 2 Correlations between study variables.

Dimensions	COP	AIPLOC	VOLI	CHO	REL
COP	1.000	.128*	.113*	.153**	.108*
AIPLOC	.128*	1.000	.338**	.543**	.631**
VOLI	.113*	.338**	1.000	.209**	.366**
CHO	.153**	.543**	.209**	1.000	.571**
REL	.108*	.631**	.366**	.571**	1.000

COP, competence; AIPLOC, autonomy IPLOC; VOLI, volition; CHO, choice; and REL, relatedness.
*Correlation is significant at the 0.05 level (1-tailed).
**Correlation is significant at the 0.01 level (1-tailed).

satisfaction for Sport Scale (BPNSS) Questionnaire in English. All subscales Cronbach's internal reliability coefficients were excellent.

Procedures

First, Bahir Dar university sports academy's ethics commission approved the research project: the validation of BNSSS's use with Ethiopian athletes, followed by by research in to relationship among motivation in sport and sports performance. The leading author then met with the team captains and head coaches to discuss the purpose of the study, presenting them with a letter from the sports academy dean's office asking for their voluntary cooperation during the data collection process. Then permission was granted to collect data directly from the participants. In order to ensure that the responses provided by the athletes were more informative of their psychological states, questionnaires were issued to the participants during the competitive season. Four data collectors distributed the BNSSS questionnaire to the athletes after briefing the overall purpose of the data collection. To translate and adapt the BNSSS instrument from its original English language version, first developed by (14) to Amharic' the methodological procedures recommended by Vallerand (17) and endorsed by Banville et al. (18) was followed:

1. An initial translation with the assistance of three translators who were proficient in the English and Amharic language;
2. Evaluation of the initial Amharic version by four experts independently;
3. Four additional experts collectively examinedall the items until they reached a consensus on item wording;
4. We administered this version of the questionnaire to 81 (men = 45; women = 36) independent athletes from four team and three individual sport types to assess item clarity and accuracy (pilot study);

TABLE 4 Frequentist statistics scale reliability of men and women BNSSS $N = 321$.

Estimate	McDonald's ω	Cronbach's α
Point estimate	0.868	0.858
95% CI lower bound	0.847	0.836
95% CI upper bound	0.889	0.879

5. Two Amharic language experts conducted a final review of the Amharic version of the BNSSS to ensure correct syntax, spelling, and grammar were correct/(Final version).

Data analysis

The data sets of 321 participants were first looked at for possible missing data and the verification checked for potential outliers. The skewness and kurtosis of the replies were used to evaluate the items' univariate normality Table 5. The statistical package for social sciences (SPSS) version 26.0 software was utilized to calculate the descriptive statistics Table 5 on a sample size of 321 data. Alpha coefficients were used to assess the internal consistency of sub scale (19).

A value of alpha coefficient above 0.7 is typically recommended and suggested threshold value and defined as acceptable for internal consistency (20–22). Furthermore, a criterion for retaining or removing items from the measurement model was a significant factor loading of greater than 0.5 with modification index.

Hair et al. (23) stated that all standardized factor loadings should be at least 0.5 and, ideally, at least 0.7.factor loading. Scale score analysis was carried out using confirmatory factor analysis (CFA). Using LISREL 8.5, CFAs were performed to confirm the factorial structure of the five dimensions of the Ethiopian version of the BNSSS. Only the desired construct was allowed to load the item scores. Error phrases were not allowed to correlate, but factors were. To assess model fit, a variety of goodness-of-fit indices were employed. They included the non-normed fit index (NNFI), comparative fit index (CFI), standardized root mean square error (SRMR), and root mean square approximation error (RMSEA). The chi-square ($x^2 = 301.974$, DF = 160), NNFI, and CFI were also among them. Values of NNFI, CFI > .90, and RMSEA.08 have historically been employed as indicators of an adequate fit (24). Hu and Bentler (25), who made this suggestion more recently, said that NNFI and CFI values of at least 0.95 were necessary for satisfactory model fit, whereas SRMR and RMSEA shouldn't go over 0.08 and 0.06, respectively. However, using these more

TABLE 3 Descriptive statistics and intra-class coefficients of BNSSS subscale scores.

Subscales	Test					Re-test					
	α	M	SD	CR	AVE	α	M	SD	CR	AVE	ICC
Competence	.880	559	.71	.88	.59	.93	551	.82	.92	.724	.929
Volition	.882	60	.84	.72	.88	.91	597	.89	.908	.769	.896
Choice	.879	52	12	.88	.65	.97	49	14	.973	.903	.973
Iploc	.848	61	.85	.85	.65	.94	59	11	.940	.841	.931
Relatedness	.869	52	114	.56	.87	.96	534	112	.956	.814	.954

α, Alpha; M, Mean; SD, standard deviation; CR, composite reliability; AVE, average variance extracted; ICC, intra-class correlation.

TABLE 5 Descriptive statistics and item-factor loadings of BNSSS item scores and cronbach's alpha.

Dimension	Item number	M	SD	Skewness	Kurtosis	IFL	ET	α
Competence	6	5.55	.904	−.392	−.446	.72	.52	.880
	11	5.60	.879	.005	−.520	.76	.58	
	12	5.62	.873	−.117	−.253	.84	.71	
	14	5.45	.958	−.104	−.341	.74	.54	
	17	5.73	.812	−.442	−.035	.80	.64	
AIPLOC	2	5.99	1.012	−1.539	2.312	.72	.52	.848
	15	6.23	.894	−1.943	4.088	.83	.69	
	16	6.10	1.004	−1.467	1.328	.87	.66	
Autonomy volition	3	6.06	.967	−.947	.802	.91	.83	.882
	5	5.97	.925	−.774	.228	.82	.67	
	8	6.09	.909	−.789	−.190	.81	.66	
Autonomy choice	4	5.27	1.470	−1.567	2.018	.83	.69	.879
	9	5.44	1.524	−1.925	3.532	.78	.60	
	13	5.17	1.488	−1.018	.188	.84	.70	
	20	4.98	1.556	−.884	−.434	.78	.60	
Relatedness	1	5.20	1.512	−1.170	.295	.79	.63	.869
	7	5.40	1.319	−1.931	4.664	.72	.52	
	10	5.21	1.470	−1.348	.991	.74	.54	
	18	5.24	1.402	−1.300	1.816	.76	.57	
	19	5.45	1.334	−1.866	3.979	.78	.61	

M, Mean; SD, standard deviation; IFL, item-factor loadings; Et, error term.

TABLE 6 Fit indices for five model BNSSS.

Parameters	X^2	DF	*P*-value	X^2/DF	GFI	RMSEA	TLI	NFI	CFI	IFI	SRMR	RMR
Values	301.97	160	<0.001	1.887	0.91	0.053	0.95	0.916	0.958	0.958	0.0469	0.069

difficult cutoff values could lead to more Type I mistakes (26). As a result (25), Criteria were employed to indicate very good fit while the old criteria were used to indicate good model fit. The item level mean scores ranged from 4.84 (SD: 1.85; autonomy choice item 20) to 6.17 (SD: .89; autonomy volition, item 8 represents lowest standard deviation value), according to the descriptive statistics for the BNSSS components. The range of SD was found to be between .84 for item 12 on competence to 1.82 for item 20 on autonomy and choice. In the CFA, the model was investigated using the maximum likelihood estimation technique.

Results

The data analyses showed that the single-factor model fits the data well Table 6 CMIN/DF. = 1.887, CFI = 0.958, TLI = 0.950, GFI = .93, IFI = 0.958, RMSEA = 0.053; RMR = .069; and SRMR = 0.469. Statistics showed that the standardized factor loadings were significant Figure 1.

A measurement model was first used to assess the later-presented structural equations model (SEM), which corresponded to a confirmatory factorial analysis (CFA) and allowed for the building of scale validity. "The cronbach's alpha values are 0.880 for competence, 0.848 for autonomy- internal perceived locus of causality, 0.882 for autonomy-volition, 0.879 for autonomy-choice, and 0.869 for relatedness, indicating high internal consistency both Cronbach's alpha and Mc Donalds Omega across all subscales Table 3 and Table 4."

The floor and ceiling effect for BNSSS data in Table 7 showed that the scale is appropriately sensitive, the sample is representative and the distribution of scores reflects the actual distribution of basic need satisfaction among the population of interest. Additionally the data is reliable which is consistent scores across different measurement (27). In essence, a good floor and ceiling effect for BNSSS data suggests that the scale is working as intended and that the data collected is meaningful.

In Table 3 above the result indicated that an excellent value of AVE and CR exhibiting strong convergent and discriminant validity as well as high internal consistency. Acceptable AVE indicates that the latent variables explain a substantial amount of variance in their respective items suggesting good construct validity while the acceptable value of composite reliability suggest the items are highly correlated, indicating strong internal consistency and reliability of the construct. We plan to address this critical gap concurrent validity in future research by outline proposed methods, such as correlating the scale with other relevant measures or comparing scores between different groups.

Discussion

BNSSS which is grounded to SDT is newly developed questionnaire for assessing athletes applied to sport competitive context (14). The current study was aimed at translating, adapting and validating the Ethiopian version BNSSS and its SDT framework.

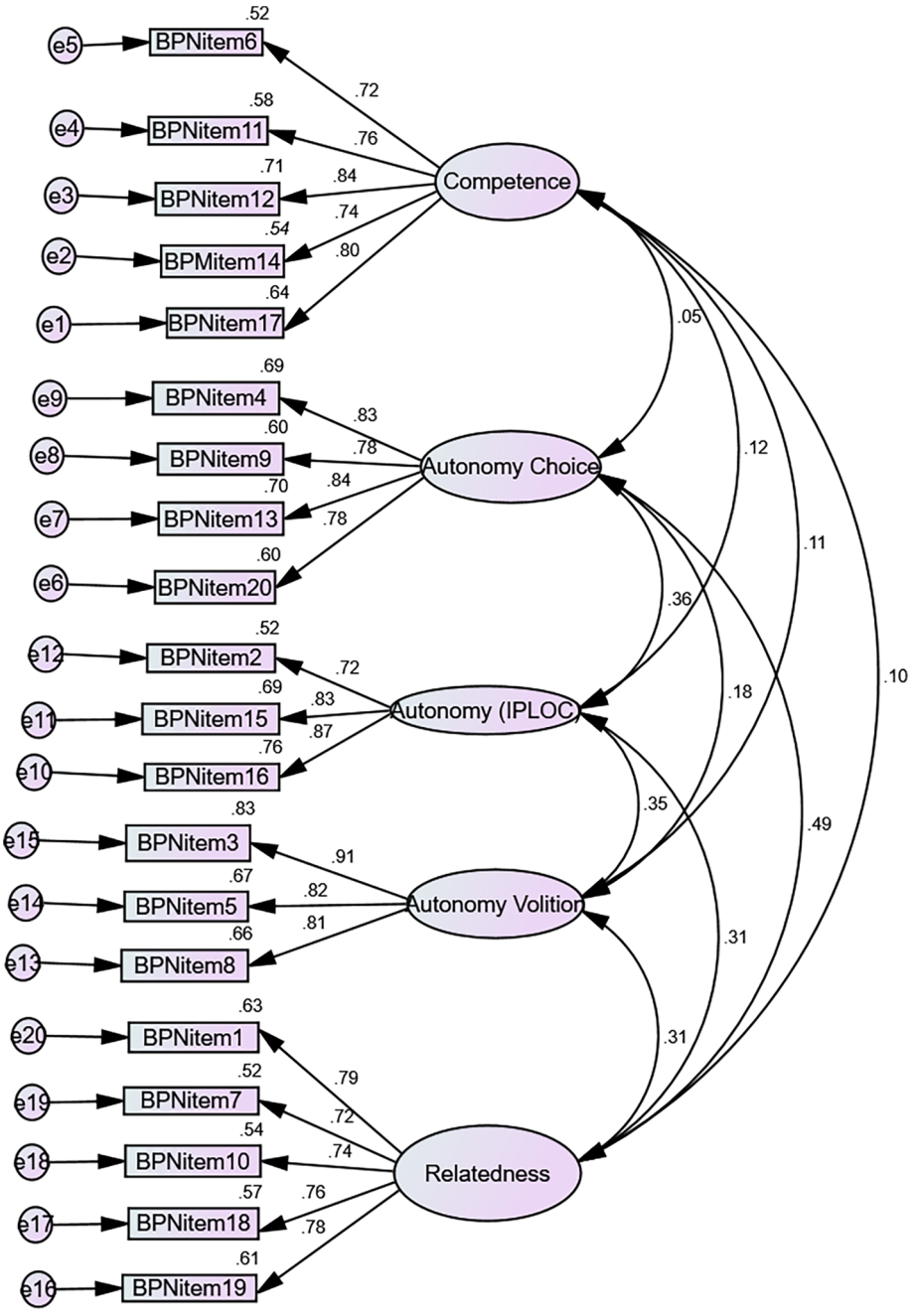

FIGURE 1
Factor structure of BNSSS item scores.

After the translation process, EFA conducted to establish the construct validity of BNSSS Ethiopian version. The data from this study were better fit for the model.

"Research has continually highlighted the importance of psychological capacities, such as decentering ability, in modulating the impact of psychological conditions on sports performance (28). In the context of our study, the findings suggest that the validity of the BNSSS scale might be influenced by similar mediating or moderating factors, as explored in the moderated mediation model by Diotaiuti et al. (28). This perspective is crucial for understanding how athletes' basic psychological needs can be better met, directly influencing their motivation and performance."

The goal of this study was to translate, adapt, and test the reliability and validity of the Ethiopian version of the Basic Need Satisfaction Sport Scale Questionnaire for team sports. The 20-item, five-factor BNSSS was developed to assess satisfaction with basic psychological needs such as competence, autonomy, and relatedness (29), which is based on self-determination theory. The autonomy construct consists of ten items divided into three subcategories: choice (four items), IPLOC (three items), and volition (three items); the other construct of basic psychological

TABLE 7 The ceiling and floor effect of each BNSSS items.

Maximum and minimum percent of scores			
Dimensions	Items	Minimum	Maximum
Competence	Co 6	7.6%	13%
	Co 11	1.96%	10.3&
	Co 12	7.8%	14.8%
	Co 14	2.35%	11%
	Co 17	2%	11.5%
IPLOC	IP 2	2.7%	13.9%
	IP 15	2.9%	14.3%
	IP 16	2.19%	13.47%
Volition	Vol 3	1.897%	10.33%
	Vol 5	1.6%	12.7%
	Vol 8	2.36%	11.33%
Choice	Cho 4	1.92	9.46
	Cho 9	2.26	10.89
	Cho 13	1.93	12.59
	Cho 20	1.99	7.2
Relatedness	Rel 1	2.13	11.47
	Rel 7	1.56	9.15
	Rel 10	1.79	10.6
	Rel 18	2.12	11.4
	Rel 19	2.26	13.9

needs, such as relatedness and competence, contains five items each. The subsequent CFA supported the five-factor BNSSS model (competence, relatedness, autonomy choice, autonomy volition, and autonomy internally perceived locus of causality (IPLOC).

The result indicated that the Ethiopian version showed adequate reliability and validity or replicated of the original and other subsequent version (7, 14, 30), for this sample. In terms of scale reliability, the subscales had acceptable internal consistency, with values comparable to those reported in the previous study. In terms of model fit, this study obtained a good fit for the original BNSSS with X2/DF = 1.887, CFI = 0.958, and RMSEA = 0.053. The findings align with previous research (14, 30).

The correlation between BNSSS subscales in Ethiopian version were higher than those in the original version studied by (14), suggesting that the translated scale may be particularly coherent in the context of Ethiopian sports.

The present study had some limitations. One of them was that it was limited to ball game athletes and had a sample size of 321; that is, the study excluded individual sports and very young athletes. As a result, it is recommended that it would be studied comprehensively in a diverse group of Ethiopian athletes with varying levels of athletic involvement. We also recommend as Ethiopia is multilingual country so as athletes speak different language, the questionnaire has to be translated accordingly. Additionally future studies can use interview session. Finally, as (14) stated, "Scale development" is "an ongoing" process, so it is a guarantee to researchers in the future to investigate the advancement of the scale.

Conclusion

In conclusion, the findings of this current study, which investigated the reliability and validity of the Ethiopian version BNSSS, show that all five dimensions have high levels of validity and internal consistency. The study's main findings indicate that satisfaction levels with the three sub dimensions of autonomy, competence, and relatedness BPN in sport are high. Furthermore, a significant and positive correlation was found between the five basic psychological needs (BNSSS) constructs. It has been discovered that satisfaction with BPN is an excellent predictor of self-determination theory. The results emphasize the importance of satisfying BPN for enhancing athlete's motivation and performance. "In conclusion, the study validates the Amharic version of the BNSSS, confirming its reliability and validity for assessing the satisfaction of basic psychological needs among Ethiopian athletes. This supports the scales applicability in diverse cultural settings, there by extending its utility beyond the initial validation context," We recommend using it to assess athlete satisfaction in various regions of the country, at various age levels, and in individual sports.

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 Bahir Dar university sports academys ethics commission approved the research project.

Author contributions

GM: Conceptualization, Data curation, Formal Analysis, Methodology, Validation, Writing – original draft, Resources. ZT: Conceptualization, Data curation, Formal Analysis, Software, Supervision, Writing – review & editing, Resources. SR: Conceptualization, Formal Analysis, Methodology, Software, Supervision, Writing – review & editing, Resources.

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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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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Luis Leitão,
Instituto Politecnico de Setubal (IPS), Portugal
Liliana Ricardo Ramos,
Polytechnic Institute of Santarém, Portugal

*CORRESPONDENCE
Ping Wang
✉ hkswp2003@aliyun.com

†These authors have contributed equally to this work

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Exploring the sports participation, muscle-strengthening exercise and active commuting with comorbidity of depression and anxiety among Chinese children and adolescents: a cross-sectional study

Bin Feng[1†], Fuchen Luo[1†], Yu Chen[1], Yuhang Zhao[2], Ping Wang[3,4*] and Ran Bao[5,6]

[1]Department of Physical Education, Tianjin College, University of Science and Technology Beijing, Beijing, China, [2]Department of Physical Education, Beijing Zhengze School, Beijing, China, [3]Institute of Sports Science, Harbin Sport University, Harbin, China, [4]Department of History, Fudan University, Shanghai, China, [5]Centre for Active Living and Learning, University of Newcastle, Callaghan, NSW, Australia, [6]College of Human and Social Futures, University of Newcastle, Callaghan, NSW, Australia

Prior research has shown that physical activity (PA) is a crucial element for preserving and enhancing health, particularly among children and adolescents, and consistent engagement in PA offers numerous advantages for sustaining typical physical and mental well-being.

Purpose: Hence, the primary objective of this study was to examine the relationship between sport participation, muscle-strengthening exercise (MSE), and active commuting (AC) in the co-occurrence of depression and anxiety in Chinese children and adolescents.

Method: This cross-sectional investigation occurred in various cities across the southeastern region of China between March 2021 and October 2021. A convenient sampling method was utilized. We invited children and adolescents to participate in the questionnaire survey. A total of 1,996 participants completed the questionnaires with the endorsement of their parents or guardians under the supervision of schoolteachers and headmasters. Girls comprised 47.5% of the participants, and the average age of participants was 14.8 ± 2.0 years. We conducted a logistic regression analysis, including 95% confidence intervals, to explore the association between sports participation, MSE, AC, and the co-occurrence of depression and anxiety.

Results: No significant association was observed between weekday active commuting for travelling to and from school and MSE and the comorbidity of depression and anxiety in children and adolescents. A negative association was only detected for those who engaged in muscle-strengthening exercises 4 days a week (OR = 0.540, 95% CI = 0.345–0.845) compared to those who did not partake in such exercises.

Conclusion: The present study has provided evidence of the connection between sports participation and the co-occurrence of depression and anxiety among Chinese children and adolescents. Sports participation is more likely to help adolescents relieve anxiety and depression than AC, MSE. In forthcoming research, it is imperative to delve deeper into strategies

that enhance the impact of sports on the mental well-being of children and young individuals. Furthermore, optimizing the magnitude of this effect may be achievable by focusing on neurobiological, behavioral, and psychosocial mechanisms.

KEYWORDS

sport participation, muscle-strengthening exercise, active school travel, depression, adolescents, children

1 Introduction

Mental health is closely related to adolescents' learning and development, interpersonal relationships, self-esteem, and self-awareness (Demirci et al., 2022; Liu T. et al., 2023). Mental health refers to a person's regular, stable, and adaptive state in thought, emotion, and behavior, so a healthy mental state can help children and adolescents better grasp learning content and face life's challenges (Sonuga-Barke et al., 2016). Shanahan and other scholars (2014) (Shanahan et al., 2011) found that the effect of mental health on children's school performance was significant, with students in better mental health performing better academically than those in worse mental health. In addition, Collishaw (2015) points out that mental disorders may lead to impaired social functioning in adolescents, which in turn may affect their relationships. However, many adolescents can face mental health issues such as anxiety, depression, and attention-deficit/hyperactivity disorder, which can lead to emotional and behavioral problems and even affect their learning and development (Sonuga-Barke et al., 2016). Depression and anxiety often co-exist, and the causes and risk levels are similar and related. For example, genetic factors and stress from life events all play a role in the onset of depression and anxiety and are all influenced by personality traits and social factors (Panza et al., 2020). In addition, depression and anxiety also share many clinical features and diagnostic tools, such as the presentation of anxiety and depression symptoms is similar (Eijsbouts et al., 2021), and commonly used assessment tools such as the Hamilton Depression Scale and the Baker Self-Rating Anxiety Scale (Zhou et al., 2022a). Therefore, in terms of treatment methods and interventions, the management of depression and anxiety can learn from each other, such as cognitive behavioral therapy, medication, and psychological counselling. Wakschlag et al. (2019) study found that the treatment effect of early intervention in children and adolescents is better, which can effectively reduce the occurrence of psychological disorders. At the same time, early intervention and treatment can prevent the long-term impact of mental health problems in children and adolescents on their lives and work as adults (Yoshikawa et al., 2012). Starting from the importance of mental health, Hermann et al. (2022) analyze that mental disorders can negatively affect a person's thoughts, feelings, and behavior in many ways, especially considering the attention-seeking and emotionally sensitive characteristics of adolescents. The incidence of mental disorders among children and adolescents has been increasing year by year, which means that schools and families need to pay more attention to mental health problems and take action to prevent and treat them. By providing services such as mental health education and psychological counselling, adolescents can be helped to better understand and cope with their emotional and behavioral problems, allowing them to build confidence, healthy relationships, and self-perception (Coghill and Sonuga-Barke, 2012).

Physical activity (PA) is an essential part of maintaining and promoting health (Pinto et al., 2020; Shen et al., 2020; Chen Z. G. et al., 2022; Fan et al., 2022; Li et al., 2024), especially for children and teenagers, and regular PA has many benefits not only in maintaining normal functioning physically and mentally (Lindsay-Smith et al., 2019; Liu et al., 2022; Li et al., 2023; Zheng et al., 2023) but also in academic ability and social communication (Liu et al., 2022; Zhang et al., 2023). Physically, PA directly promotes cardiovascular health, continues human vitality, and reduces the risk of obesity by building bone and muscle strength (Luan et al., 2019; Zheng et al., 2023). Studies have also shown that PA is negatively correlated with the incidence of chronic diseases such as diabetes and cardiovascular disease (Sallis et al., 2021). Mentally, regular PA can relieve mental stress and reduce the incidence of depression and anxiety symptoms in adolescents (Kang et al., 2021; Wolf et al., 2021; Zheng et al., 2023). More importantly, the team sports attached to PA can boost self-confidence, which is beneficial for fostering a sense of cooperation and social inclusion (Yan et al., 2024b). Cognitively, appropriate regular PA can relieve mental stress and reduce the incidence of depression and anxiety symptoms in children and adolescents. It helps improve attention and memory (Zhou et al., 2022b) and promotes academic performance (Li et al., 2023). The World Health Organization (WHO) prioritises PA in its guidelines, recommending that children and adolescents get at least 60 min of moderate-to-vigorous physical activity (MVPA) per day (Yan et al., 2024b). Regular PA can play a crucial role in promoting the overall development of young people and fostering healthy lifelong habits.

Regarding sports participation, it is the actions and attitudes of students initiatively participating in sports activities, which is just an overall description of sports objectives (Ren et al., 2021; Santos-Pastor et al., 2022; Liu T. et al., 2023). From the angle of sociology and psychology, sports participation is a significant way to realize kids' socialization, which refers to a socialization procedure in essence (Dorsch et al., 2009; Yan et al., 2023). Apart from that, sports participation indicates success and the investment of psychological energies, and different students devote different energies to activities according to time and objectives (Farias et al., 2017). Such a concept includes the activity's external indicators (e.g., mood) and the exercise goals. As pointed out by Wicker and Frick (2015), females and males exercising more frequently have better health. However, for females, the difference in subjective health is partly attributed to education, deprivation of economy, and family-work pressure. As Eime et al. (2013) claimed, regular physical activities prevent chronic diseases

and decrease the risks of premature death. Likewise, Kantomaa et al. (2015) demonstrated that high physical activity levels have a positive relationship with the health of adolescents. As suggested by other research, exercise is favorable to enhancing people's self-rated health (Marques et al., 2017; Shi C. et al., 2022).

Sports participation is closely linked to mental well-being. Research indicates that consistent physical activity can have favourable effects on various facets of psychological health, including reducing depressive symptoms, alleviating mood, and enhancing self-esteem (Appelqvist-Schmidlechner et al., 2018). Engaging in sports facilitates the release of endorphins and natural mood enhancers and offers a channel for relieving pressure (Parker et al., 2014). Moreover, physical activity has the potential to enhance the quality of sleep, a factor of significant importance for maintaining good psychological health (Wickham et al., 2020). Furthermore, participating in physical activities can provide social support, a crucial factor in promoting psychological well-being (Laird et al., 2018; Zheng et al., 2023). Exercise can also give a sense of purpose by serving as a distraction from negative thoughts (Eime et al., 2013). Therefore, Easterlin et al. (2019) emphasized the significance of integrating sports participation into daily life to maintain psychological health. Simultaneously, it is crucial to identify enjoyable and sustainable physical activities to ensure ongoing involvement and psychological well-being.

Participating in adequate and consistent PA is strongly linked to higher levels of health-related physical fitness in children and adolescents, making it a significant contributor to improved physical fitness (Shi J. et al., 2022), as demonstrated in the literature. However, these studies primarily examined overall physical activity levels rather than focusing on the specific modes. Consequently, recent research has emphasized the need to investigate the relationships between different modes of physical activity and health-related physical fitness among children and youth. Children and adolescents engage in various modes of physical activity, some of which have demonstrated significant associations with health outcomes and fitness components. Among these different modes, sports participation, muscle-strengthening exercise (MSE), and active school travel (AST) stand out as three fundamental forms of physical activity among adolescents (Huang et al., 2021; Shi J. et al., 2022). Sports participation often occurs within school settings, while AST is a daily routine, and both modalities play pivotal roles in monitoring an active lifestyle on a global scale (Nweke et al., 2019). Concerning muscle-strengthening exercise (MSE), the WHO recommends that young individuals engage in such activities a minimum of three times per week (Chaput et al., 2020). Moreover, a considerable amount of evidence indicates a connection between sports participation, muscle-strengthening exercise (MSE), and active school travel (AST) with mental health outcomes in adolescents (Lee et al., 2019; Huang et al., 2021; Shakespear-Druery et al., 2021; Müller et al., 2022).

The close connection between long-term physical activity and mental disorders, such as depression and anxiety, can be attributed to alterations in brain function and structure (Matta Mello Portugal et al., 2013). Specifically, long-term physical activity participation can promote neurogenesis, angiogenesis and synaptogenesis, potentially mitigating depression and anxiety (Matta Mello Portugal et al., 2013). Moreover, sports participation necessitates concentration, emotional regulation, and coping strategies (Robazza et al., 2004). These elements, associated with enhanced physical performance, may alleviate depression and anxiety among participants. Additionally, the central nervous system, accountable for neuromuscular activities and task execution, may offer anticipatory control that could help ward off psychological depression and anxiety (Matta Mello Portugal et al., 2013). Further, the underlying mechanisms connecting muscular training activities and mental disorders, such as depression and anxiety, remain to be fully understood. Potential explanations could include enhanced social interaction and expectations (Gordon et al., 2017). However, there is a shortage of evidence on the benefits of sports participation, MSE, and AC about the comorbidity of depression and anxiety in adolescents. To address this research gap, the current study aims to explore the relationship between sports participation, MSE, and AC and the coexistence of depression and anxiety among Chinese adolescents. This investigation intends to provide empirical evidence to fill this gap in the existing literature.

2 Methods

2.1 Participants and procedure

The cross-sectional study employed a convenient sampling method. The data collection was conducted in the Southeast regions of China between March 2021 and October 2021. The current study included public school-school adolescents in grades 4, 5, 7, 8, 10, and 11. Students in grades 9 and 12 were excluded as they prepared for the General High School Academic Proficiency Test and the National College Entrance Examination, respectively. For each grade, two classes were selected using a convenient sampling method. Before the commencement of data collection, participants were provided with detailed instructions on the data collection process. Children and adolescents with physical or intellectual disabilities were not included in the current study. A total of 2,374 participants consented to participate in this survey. After removing invalid data (such as providing invalid answers or missing answers), 1996 children and adolescents who completed the study and offered valid information were included in the final analysis. Girls comprised 47.5% of the participants, and the average age of participants was 14.8 ± 2.0 years. Formal written permission and consent were obtained from participants and their parents. Participants who provided information on the relevant variables were included in the study. Those who did not report data on required variables (e.g., independent variables, outcomes, and covariates) were excluded from the initial sample. Additionally, all respondents and their guardians or parents were informed that participation in the survey was entirely voluntary. This study was approved by the Research Board at Shanghai University of Sport (Approval Number: 102772021RT071).

2.2 Measures

2.2.1 Sport participation

A single item was used to analyze sports participation, stated below: "Over the past 12 months, have you participated in a sports club, a sports team, or a sport-related activity?" The possible answers to such a question include never, 1–3 times per month, 1–2 times per week, and above three times per week. Such a measurement item has been confirmed to be a reliable and effective question for evaluating adolescents' sports participation (Lian et al., 2021; Liu T. et al., 2023).

MSE was evaluated through the inquiry: *"Over the past week, how frequently did you participate in activities aimed at strengthening or toning your muscles, such as push-ups, sit-ups, or weightlifting?"* The possible responses were: *0 = none, 1 = 1 day, 2 = 2 days, 3 = 3 days, 4 = 4 days, 5 = 5 days, 6 = 6 days, and 7 = 7 days.* This metric has been established as a reliable and valid tool for evaluating MSE in Chinese children and adolescents (Xin et al., 2021; Wang et al., 2024). According to the World Health Organization's guidelines, individuals who reported engaging in such activities for three or more days were categorised as meeting the MSE recommendation, while those who reported fewer than 3 days were classified as not meeting the guideline (Chaput et al., 2020).

AST was measured by using two distinct inquiries: (1) *"During weekdays, how frequently did you use active means such as walking or cycling to travel to school?"* and (2) *"On weekdays, how often did you use active transportation methods like walking or cycling to return home after school?"* For both questions, respondents selected from 0 to 5 days as their response. These two items have been used in Chinese children and adolescents (Gu and Chen, 2020; Chen et al., 2021).

2.2.2 Depressive symptoms and anxiety

The Chinese version of the 9-item Patient Health Questionnaire (PHQ-9) was applied to analyze depressive symptoms. This tool included nine items related to depressive symptoms within the past 2 weeks. Each item used a Likert four-point scale, from 0 (none) to 3(almost daily). The total score ranged from 0 to 27. The higher the score, the more severe depressive symptoms will be. According to PHQ-9 scoring, the severity of depressive symptoms was classified as 0-4(minimal), 5-9(mild), 10-14(moderate), 15-19(moderately severe), and 20-27(severe). The psychological measurement properties of PHQ-9 have been tested on Chinese children, showing adequate reliability and validity (Wang et al., 2014; Chen J. K. et al., 2022).

7-item generalized Anxiety Disorder Scale (GAD-7) was used to assess anxiety disorders. This scale was composed of 7 items within the past 2 weeks. The answer to each item is applied to a Likert four-point scale (from 0 to 3). The total score of GAD-7 ranged from 0 to 21. The higher the score, the more severe the degree of anxiety. The severity of anxiety could be divided into four categories, including minimal (0–4), mild (5–9), moderate (10–14) and severe (15–21). The translated GAD-7 was widely applied among Chinese children and adolescents, showing acceptable reliability and validity (Sun et al., 2021; Zhang et al., 2021).

2.3 Statistical analysis

SPSS 26.0 was employed for all statistical analyses. As the proportion of missing data was less than 5%, the missing data was deleted from the analysis. Descriptive statistics, including the percentage for categorical variables and the mean with standard deviation for continuous variables, were utilized to present relevant features. In further analysis, the following variables were used as concomitant variables, including gender, grade, age, place of residence, rich degree of family, and whether living with parents or not (Appelqvist-Schmidlechner et al., 2018; Easterlin et al., 2019; Wickham et al., 2020). Partial correlation was adopted to investigate associations among sports participation, muscle-strengthening exercise (MSE), AST, depression, and anxiety while accounting for sociodemographic factors, BMI, gender, and grade. Generalized Linear Models with Ordinal Logistic Regression (OR) were applied to assess the relationships between sports participation, muscle-strengthening exercises, and active commuting with depressive symptoms and anxiety disorders. This evaluation was conducted after adjusting for all previously mentioned covariates. The statistical significance threshold was set at $p < 0.05$.

3 Results

Table 1 shows the characteristics of the sample. A total of 1,996 participants were included in the final analysis. Specifically, 47.5% were girls, with a mean age of 14.8 ± 2.0 years and a mean BMI of 20.8 ± 5.0. Most participants (67.6%) resided in urban areas, while 21.4% lived in suburban areas and 10.9% in rural areas. Half of the participants had siblings, and the majority (84.6%) lived with their parents. Over half of the students reported that their fathers had only a high school diploma or less, while 36.8% of fathers had an undergraduate degree and 6.4% had a graduate degree. Similarly, over half of the students indicated that their mothers had only a high school diploma or less, with 35.2% having an undergraduate degree and only 3.5% having a graduate degree.

Regarding sports participation, 15.6% of students engaged 1–3 times weekly, 17.5% for 1–2 times, and 7.2% for three or more times. For muscle-strengthening exercises, 36.4% abstained, 18.5% engaged once weekly, 21.0% for twice, 11.4% for three times, 4.4% for four times, and 8.3% for five times. Additionally, 36.6% actively commuted to school daily, with 3.2, 3.6, 5.5, and 5.2% doing so for four, three, two, and 1 day(s), respectively. Similarly, 45.9% actively commuted home, with 2.7, 4.0, 5.4, and 5.8% doing so for four, three, two, and 1 day(s), respectively. Furthermore, 16.3% of respondents reported symptoms of depression, while 83.7% did not. Similarly, 12.2% reported symptoms of anxiety, while 87.8% did not. Concerning the co-occurrence of depression and anxiety, 9.9% of respondents reported experiencing both, 8.7% reported at least one, and 71.4% reported neither.

Table 2 outlines the correlation coefficients between demographic variables, sports participation, and depression and anxiety symptoms. Significant correlations were found between muscle-strengthening exercises and depression symptoms ($r = -0.066$, $p = 0.003$) and comorbidity ($r = -0.045$, $p = 0.043$). Furthermore, no significant correlation was found between sports participation, active commuting travel, depression symptoms, anxiety symptoms, or comorbidity in children and adolescents.

The relationship between sports participation, muscle strengthening, active commuting, and comorbidity is displayed in Table 3. When compared to individuals who never participated in sports, participating in sports 1–3 times per week (OR = 1.023, 95%CI = 0.723 to 1.447, $p = 0.899$), 1–2 times per week (OR = 1.175, 95%CI = 0.832 to 1.660, $p = 0.360$), and more than three times per week (OR = 0.791, 95%CI = 0.453 to 1.380, $p = 0.409$) was not associated with a lower incidence of comorbidity. Additionally, no association between active commuting to school and back home on weekdays and

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TABLE 1 Sample characteristics.

		n/mean	%/sd
Continuous variables			
Age		14.08	±2.0
Body mass index		20.81	±5.0
Categorical variables			
Gender			
	boy	1,048	52.5
	Girl	948	47.5
	Total	1996	100.0
Residence			
	Rural	218	10.9
	Suburban	428	21.4
	Urban	1,350	67.6
	Total	1996	100.0
Siblings			
	Yes	1,005	50.4
	No	991	49.6
	Total	1996	100.0
Live with parent			
	Yes	1,689	84.6
	NO	307	15.4
	Total	1996	100.0
Grade			
	4	218	10.9
	5	242	12.1
	7	295	14.8
	8	356	17.8
	10	484	24.2
	11	401	20.1
	Total	1996	100.0
Mother Education Level			
	Middle school or below	576	28.9
	High school	558	28.0
	Undergraduate	735	36.8
	Graduate	127	6.4
	Total	1996	100.0
Father Education Level			
	Middle school or below	707	35.4
	High school	481	24.1
	Undergraduate	703	35.2
	Graduate	105	5.3
	Total	1996	100.0
Sport participation			
	Never	1,190	59.6
	1--3 times per month	312	15.6
	1--2 times per week	350	17.5
	3 or more times per week	144	7.2
	Total	1996	100.0
AST in weekday (go to school) 1			
	0	917	45.9
	1 day	104	5.2
	2 day	109	5.5
	3 day	71	3.6
	4 day	64	3.2
	5 day	731	36.6
	Total	1996	100.0
AST in weekday (after school) 2			
	0	828	41.5
	1 day	115	5.8
	2 day	108	5.4
	3 day	80	4.0
	4 day	53	2.7
	5 day	812	40.7
	Total	1996	100.0
Muscle strengtheninghoning exercises (past 7 days)			
	0	726	36.4
	1 day	370	18.5
	2 day	420	21.0
	3 day	228	11.4
	4 day	87	4.4
	5 day	165	8.3
	Total	1996	100.0
Depressive			
	No	1,671	83.7
	Yes	325	16.3
	Total	1996	100.0
Anxiety			
	No	1753	87.8
	Yes	243	12.2
	Total	1996	100.0

comorbidity in adolescents was found. A negative association was only found for participating for 4 days (OR = 0.540, 95% CI = 0.345–0.845) and comorbidity compared to those who did not participate in muscle strengthening exercise.

TABLE 2 The correlation coefficients between demographic variables, sports participation and depression and anxiety symptoms.

Variables	Age	BMI	Gender	Grade	Residence	Siblings	Live with parent	Mother education level	Father education level	AST in weekday (go to school)	AST in weekday (after school)	Muscle strengthening exercises (past 7days)	Sport participation	Depressive	Anxiety	Comorbidity
1.Age	1															
2.BMI	0.190**	1														
3. Gender	0.01	−0.093**	1													
4. Grade	0.958**	0.188**	0.02	1												
5. Residence	−0.01	0.03	0.01	−0.02	1											
6. Siblings	−0.054*	−0.051*	0.04	−0.01	−0.310**	1										
7. Live with parent	0.02	0.03	−0.01	0.02	−0.137**	0.077**	1									
8. Mother Education Level	−0.00	−0.04	0.057*	−0.04	0.412**	−0.424**	−0.160**	1								
9. Father Education Level	−0.02	−0.03	0.04	−0.063**	0.397**	−0.430**	−0.153**	0.730**	1							
10. AST in weekday (go to school)	−0.064**	−0.04	−0.069**	−0.077**	0.00	−0.02	0.03	0.072**	0.066**	1						
11. AST in weekday (after school)	−0.085**	−0.03	−0.048*	−0.106**	0.060**	−0.069**	0.01	0.109**	0.122**	0.824**	1					
12. Muscle strengthening exercises(past 7 days)	−0.182**	−0.085**	−0.132**	−0.196**	0.158**	−0.094**	−0.052*	0.176**	0.143**	0.088**	0.091**	1				
13. Sport participation	−0.237**	−0.085**	−0.107**	−0.259**	0.122**	−0.132**	−0.053*	0.174**	0.192**	0.131**	0.131**	0.362**	1			
14. Depressive	0.083**	0.070**	−0.00	0.085**	0.04	−0.00	0.102**	0.02	0.04	0.01	0.01	−0.066**	−0.01	1		
15. Anxiety	0.059**	0.04	0.04	0.063**	0.04	−0.01	0.071**	0.03	0.059**	0.01	0.00	−0.01	−0.01	0.653**	1	
16. Comorbidity	0.079**	0.063**	0.01	0.082**	0.04	−0.01	0.096**	0.03	0.054*	0.01	0.00	−0.045*	−0.01	0.920**	0.897**	1

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

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TABLE 3 Parameter estimates obtained from the logistic regression model based on the outcome of AST, MSE, and sport participation.

Parameter			95% Wald confidence interval		Hypothesis test				95% Wald confidence interval for exp (B)	
Threshold		B	Lower	Upper	Wald chi-square	df	Sig.	Exp (B)	Lower	Upper
[AST in weekday (go to school) = 6]	[Comorbidity = 0]	0.02	−2.63	2.67	0.00	1	0.99	1.02	0.07	14.50
	[Comorbidity = 1]	0.79	−1.86	3.45	0.34	1	0.56	2.21	0.16	31.42
[AST in weekday (go to school) = 5]		0.02	−0.45	0.50	0.01	1	0.93	1.02	0.64	1.64
[AST in weekday (go to school) = 4]		0.29	−0.59	1.17	0.42	1	0.52	1.34	0.56	3.22
[AST in weekday (go to school) = 3]		0.38	−0.35	1.10	1.03	1	0.31	1.46	0.70	3.01
[AST in weekday (go to school) = 2]		0.03	−0.61	0.67	0.00	1	0.92	1.03	0.54	1.95
[AST in weekday (go to school) = 1]		−0.30	−0.97	0.36	0.81	1	0.37	0.72	0.38	1.44
[AST in weekday (after school) = 6]		0[a]								
[AST in weekday (after school) = 5]		−0.05	−0.53	0.42	0.05	1	0.83	0.95	0.59	1.53
[AST in weekday (after school) = 4]		−0.56	−1.52	0.40	1.30	1	0.25	0.57	0.22	1.49
[AST in weekday (after school) = 3]		0.39	−0.27	1.05	1.34	1	0.25	1.48	0.76	2.85
[AST in weekday (after school) = 2]		0.05	−0.60	0.69	0.02	1	0.89	1.05	0.55	2.00
[AST in weekday (after school) = 1]		0.01	−0.60	0.62	0.00	1	0.98	1.01	0.55	1.85
[Muscle strengtheninghoning exercises(past 7 days) = 6]		0[a]								
[Muscle strengtheninghoning exercises(past 7 days) = 5]		−0.48	−1.01	0.05	3.14	1	0.08	0.62	0.36	1.05
[Muscle strengtheninghoning exercises(past 7 days) = 4]		−0.62	−1.32	0.08	3.00	1	0.08	0.54	0.27	1.09
[Muscle strengtheninghoning exercises(past 7 days) = 3]		−0.62	−1.06	−0.17	7.26	1	0.01	0.54	0.34	0.85
[Muscle strengtheninghoning exercises(past 7 days) = 2]		−0.28	−0.60	0.05	2.76	1	0.10	0.76	0.55	1.05
[Muscle strengtheninghoning exercises(past 7 days) = 1]		−0.28	−0.62	0.06	2.69	1	0.10	0.75	0.54	1.0
[Sport participation = 4]		0[a]								
[Sport participation = 3]		−0.23	−0.79	0.32	0.68	1	0.41	0.79	0.45	1.38
[Sport participation = 2]		0.16	−0.18	0.51	0.84	1	0.36	1.17	0.83	1.66
[Sport participation = 1]		0.02	−0.32	0.37	0.02	1	0.90	1.02	0.72	1.45

Dependent Variable: Comorbidity, Model: (Threshold), whether the MVPA guidelines are met, whether the screen guidelines are met, whether the sleep guidelines are met, AST in weekday (go to school), AST in weekday (after school), Muscle-strengthening exercises (past 7 days), Sport participation. [a] Set to zero because this parameter is redundant.

4 Discussion

This study aimed to investigate the correlation between sports participation, MSE, and AC and the concurrent occurrence of depression and anxiety in children and youth. The findings indicated that there was no significant association between weekday active commuting for school travel and MSE with the coexistence of depression and anxiety in children and adolescents. Notably, a negative association was observed only for those who participated in muscle-strengthening exercises 4 days a week compared to those who did not engage in such exercises.

In China, studies reveal significant levels of depression and anxiety among children and adolescents. For example, in Shanghai, middle school surveys found depression rates around 15.7% and anxiety rates at 23.9% (Jörns-Presentati et al., 2021). Urban areas often show higher prevalence due to academic pressure and family expectations, while rural areas face challenges in accessing mental health services (Murry et al., 2011). Gender differences exist, with females typically reporting more symptoms (Salk et al., 2017).

Our findings affirm the idea that sports participation is associated with a reduced propensity for depression and anxiety in children and adolescents. This is consistent with the conclusions of recent research firstly from the physiological

benefits of sports participation, the frequency of physical exercise participation, and the release of endorphins in a positive light, more and faster production of "feel-good" hormones can improve mood and promote well-being (Leahy et al., 2020). In addition, participation in sports is more effective in transferring negative psychology, which is particularly important for sensitive students because they are often influenced by the surrounding environment and are under tremendous psychological pressure (Salim and Winter, 2022; Pachankis and Jackson, 2023). According to research, in addition to genetic factors, the psychological problems of primary and secondary school students at this stage are mainly caused by factors such as learning pressure, family conditions, peer communication, and so on (Fegert et al., 2020; Liu X. Q. et al., 2023). Psychological problems often manifest through emotions and behaviors, such as lack of sleep, anxiety, depression, loneliness, confrontation, inattention, etc. (Hen et al., 2022). Therefore, from the efficiency perspective, sports' role in maintaining and improving people's mental health is unique and even irreplaceable. Because of these reasons and manifestations, physical education teachers should take the initiative based on the characteristics of young people and actively participate in promoting and improving the mental health of young people.

In addition, the social dimension intertwined with sports can also suppress some negative emotions. Children and adolescents who participate in sports tend to do so in teams, which can foster their sense of belonging and enhance their self-esteem (Martin et al., 2018). This sense of connection and worth can significantly reduce feelings of loneliness and loneliness, and being isolated is thought to be a significant trigger for depression and anxiety (Dale et al., 2019). At a time when adolescents must face the combined challenges of identity issues and peer pressure, engaging in physical activity can help distract them from these pressures and reduce the likelihood of developing depression (Howie et al., 2020; van Sluijs et al., 2021). Therefore, the school sports activities should be oriented to all students, focusing on collective and team activities and giving priority to diversified sports such as basketball, football, and volleyball (Carter-Thuillier et al., 2023; Eluère et al., 2023). This can ensure that everyone participates and has special skills, nourishing young people's body and mind with various sports activities. It can be seen that compared with other activities, sports activities pay more attention to the rules of games and teamwork to cultivate students' communication skills and interpersonal relationship-handling methods (Yu and Jiang, 2017).

Participation in sports can also build resilience and coping skills in adolescents, and grit can play a role in resisting negative emotions. In sports, young people often face situations that force them out of their "comfort zone, "a continuous opportunity to challenge their inertia, physical strength, and motor skills (Huang et al., 2021) through years of perseverance in honing the will to finally enjoy the process of happiness, eventually developing perseverance and optimistic character. The challenges and setbacks encountered in athletic pursuits can, therefore, teach adolescents to manage adversity and stress more effectively, thus making them less susceptible to depression.

Although participation in physical activity is protective against depression in adolescents, it is important to recognize that it is not the only solution. The influence of family environment, academic pressure, and other factors on adolescents' mental health cannot be ignored. Therefore, to promote mental health and prevent mental health problems, we must start with many aspects and comprehensive treatment. For schools, it is necessary to strengthen monitoring and precise intervention. Physical education teachers should make full use of the characteristics of physical education disciplines, give play to the advantages of strong interpersonal skills of physical education teachers, and form a helping relationship with teenagers with psychological imbalances to prevent sudden psychological problems (Yan et al., 2023; Yim et al., 2023; Yan et al., 2024a,b). Although evidence suggests that promoting youth participation in physical activity is an effective strategy to reduce the incidence of depression and anxiety disorders, the specific types and amounts of physical activity that are most beneficial for the mental health of adolescents with different personalities still need to be refined. More advice is needed on how to most effectively promote these activities among children and adolescents (Guinto et al., 2022).

In contrast to earlier research findings (Larouche et al., 2014), the current study observed no correlation between active commuting and self-reported depression and anxiety. Given that active commuting is linked to increased physical activity levels, it is plausible that it could contribute to a reduction in depression and anxiety among children and adolescents. Prior investigations indicated a positive correlation between active commuting and cardiorespiratory fitness in children and adolescents (Muntaner-Mas et al., 2018). In contrast, our current investigation contradicts previous findings. Furthermore, our study indicates a lack of association between active commuting and depression and anxiety. We considered various factors to explain why active commuting might not be linked to depression and anxiety, such as the relatively lower intensity of active commuting (e.g., walking) in children and adolescents, potential biases in self-reported measures of depression and anxiety, and the lack of robust validation for assessing active commuting. This observation might also elucidate the absence of a significant association between MSE and the co-occurrence of depression and anxiety in students. For instance, even though students participate in active commuting between school and home and incorporate muscle-strengthening or toning exercises, the duration and intensity of these activities may be limited, potentially falling below the threshold required to alleviate depression and anxiety in adolescents. Due to the scarcity of comparable evidence in this study, additional observational and intervention studies could be warranted to investigate and validate the impact of active commuting on depression and anxiety among children and adolescents.

4.1 Practical implications

The strategy that optimizes the impact of sports on kids' psychological health should be explored in future studies. Apart from that, it is essential to examine more game-based interventional and longitudinal research to enhance children's self-awareness, inner motivation, and well-being, as well as mental and physiological results (Yan et al., 2023). Notably, the SAAFE (Supportive, Active, Autonomous, Fair, Enjoyable) principle

provides a framework to design and deliver exercise sessions (Lubans et al., 2017), which was guided by the self-determination theory, these principles are applied to two HIIT researches (Hancox et al., 2018). To a certain extent, HIIT (high-intensity interval training) has an aversive nature. Still, if the design of dynamic physical activities can satisfy basic mental needs, it may be more interesting for children (Hancox et al., 2018). For example, participants can be offered choices of exercises and rest interval durations to satisfy autonomy and be given positive feedback to strengthen competence perception. Apart from that, performing vigorous physical activities in groups will become more enjoyable and meet the perception of relatedness. In this research, self-reported measures are adopted to gather all variables' data, which can be influenced by participants' social desirability and recall bias. Through cross-sectional design, the causal relationship may not be explained satisfactorily. Moreover, this study has some limitations. It should be noted that the data collection was conducted in 2021, which may result in differences between the findings and those of non-covid-19 pandemics. However, one previous study suggested a similar association between physical activity and muscle-strengthening exercises and mental health in adolescents before and during the COVID-19 pandemic (Burns et al., 2023). This emphasised the importance of physical activity in preventing depression and anxiety in adolescents, particularly in the period of the Covid-19 pandemic. Namely, except for the frequency type, no distinction is made by the movement type, and data support on the differentiation of different sports categories is not provided. Besides, during the COVID-19 pandemic, children and adolescents in China experienced heightened levels of anxiety and depression, particularly during periods of lockdowns and restrictions. Studies have shown increased psychological distress among youth attributed to factors such as social isolation, disrupted routines, and concerns about health and safety (Shanahan et al., 2022). These challenges were exacerbated by limitations on movement and social activities, which heightened feelings of loneliness and stress (Holmes et al., 2020). It is essential to conduct a prospective research design to gain a better understanding of the causal relations between sports participation, muscle-strengthening exercise, and active commuting with depression and anxiety and improve the success rate of intervention. In addition, the assessment of depression and anxiety was conducted via self-reported questionnaires. However, the potential for measurement bias may be introduced by participants' prior experiences with similar scales. Finally, convenience sampling has a disadvantage. Specifically, it is likely not very objective because it may not represent the population. Given the limitations, conducting future research to resolve problems and gain more decisive evidence is essential.

5 Conclusion

The present study substantiated that sports participation was more effective in alleviating anxiety and depression in adolescents compared to AC and MSE. Future research should delve into strategies that enhance the mental health benefits of sports for youth. Optimising the effect size may also be achieved by focusing on neurobiological, behavioral, and psychosocial mechanisms.

Data availability statement

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

Ethics statement

This study was approved by the Research Board at Shanghai University of Sport (Approval Number: 102772021RT071). 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

BF: Conceptualization, Formal analysis, Methodology, Writing – original draft. FL: Conceptualization, Writing – original draft, Writing – review & editing. YC: Writing – original draft, Writing – review & editing. YZ: Data curation, Formal analysis, Funding acquisition, Project administration, Software, Writing – original draft. PW: Formal analysis, Funding acquisition, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. RB: Conceptualization, Investigation, Software, Writing – original draft.

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Conflict of interest

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

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EDITED BY
Marianna Alesi,
University of Palermo, Italy

REVIEWED BY
Samuel Honório,
Polytechnic Institute of Castelo Branco, Portugal
María Jesús Monteagudo,
University of Deusto, Spain

*CORRESPONDENCE
JingJing Nie
✉ niejingjing@bnu.edu.cn

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An analytical study on changes in university students' attitudes toward physical activity

JingJing Nie[1,2]*

[1]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China, [2]State Key Laboratory of Cognitive Neuroscience and Learning, Faculty of Psychology, Beijing Normal University, Beijing, China

Purpose: Positive attitudes toward physical activity have been consistently linked to health Behaviors. This study aims to validate the effectiveness of attitude change in the domain of exercise and identify the mechanisms through which this change occurs in the context of sports and promote exercise behavior.
Methods: 103 university students (20.7 ± 1.97 years, 40 males, and 63 females) completed the implicit and explicit attitude tests. Based on their exercise levels assessed using the Physical Activity Rating Scale (PARS-3), participants were categorized into low and high exercise level groups. From this sample, 66 university students (19 males and 47 females) with low exercise levels completed a self-generated information task. Subsequently, physical activity was assessed through a skipping rope task.
Results: The implementation of the self-generated information task resulted in notable alterations in implicit attitudes ($\eta i^2 = 0.07$) toward physical activity during subsequent Implicit Attitude Test (IAT) evaluations. Additionally, significant changes were observed in explicit attitudes ($\eta e^2 = 0.12$) toward physical activity among university students. Moreover, the use of self-generated information positively influenced immediate exercise behavior.
Discussion: This study provides valuable insights into the impact of attitudes on behaviors among university students. It suggests that attitudes toward physical activity can be effectively changed through the use of self-generated information methodology, leading to an enhancement in immediate exercise behavior. Such attitude change has the potential to promote healthier behaviors and reduce the risk of diseases. These findings hold implications for interventions aimed at enhancing physical activity levels among university students.

KEYWORDS

attitudes toward physical activity change, implicit attitude, explicit attitude, physical activity, university students

1 Introduction

It is possible that someone may ask you, "Do you think I look good today?" Your response may be influenced by your personal attitudes towards exercise and health, as well as a preference for an active and fit lifestyle. Sometimes, we may not be fully aware of the attitudes we hold, yet they significantly impact our behavior and how we perceive the world around us. Attitude change is a fundamental concept in the study of individual behavior (1). Health behavior is not solely determined by the conscious processing of information but is also influenced by automatic processes (2). This perspective offers fresh insights into the factors that promote health-protective behaviors, such as engaging in physical activity (3). Theories on health behavior focus

on the role of attitudes as antecedents to behavior, particularly the influence of both explicit and implicit attitudes on predicting and changing behavior. Implicit and explicit cognitive processes are incorporated within dual-process models (4). The Associative-Propositional Evaluation model [APE (5)] describes implicit and explicit cognitive processes, providing a framework to understand the potential connections between automatic evaluations and exercise behavior.

1.1 Associative propositional evaluation (APE) model

Gawronski and Bodenhausen (5) proposed that implicit and explicit attitudes are two distinct types of cognitive processing and representation. The APE (Associative-Propositional Evaluation) model views the assessment of implicit attitudes as a process of associative processing. Associative processing is influenced by external stimuli and the activation of associations in memory. For instance, a chance encounter with an individual who is considered unattractive at a charity event may activate a positive impression of that person. Conversely, encountering the same individual in a dark alleyway may activate feelings of hostility towards him. The same stimulus can elicit different patterns of association in memory, leading to diverse emotional responses based on the influence of external stimuli and the structure of associations in memory. In a study conducted by Jabold (6), the author examined stereotyping against criminals and law-abiding individuals, two groups that clearly differ in valence.

In contrast, explicit attitudes are assessed through propositional processing, which is influenced by the accuracy of the information activated by associations and guided by logical reasoning. Unlike associative processing, propositional processing distinguishes between correctness and error. In the associative processing system, automatic emotional responses are transformed into evaluative judgments regarding the liking or disliking of an object, forming corresponding propositions.

The APE model, proposed by Gawronski and Bodenhausen (7) and illustrated in Figure 1, suggests that associative and propositional processing can occur independently or interactively under varying circumstances. The propositional perspective has already stimulated considerable research on automatic evaluation (8). The APE model is a research paradigm in attitude change that employs the self-generated information task (9). This paradigm is widely utilized in social psychology research and has demonstrated effectiveness in moderating stereotypes and influencing both implicit and explicit attitudes under specific experimental conditions (5).

1.2 The present research

The role of associative propositional evaluation (APE) models in attitude change has garnered support from several studies. For instance, Chang and Ko (10) examined the impact of celebrity endorsement on consumers' implicit and explicit attitudes toward brand choice using the APE model. Their findings revealed that celebrity endorsement messages activate brand-related information, leading to implicit changes in consumers' attitudes and ultimately influencing their choice of branded products.

Multiple studies have examined the influence of explicit and implicit attitudes on physical activity behavior (3, 11, 12, 35). Rebar et al. (11) demonstrated that physical activity is partly determined by non-conscious processes such as habits, automatic associations, and priming effects. Biondolillo and Pillemer (13) showed that implicit attitudes toward physical activity can be modified, and positive implicit attitudes can be elicited through pleasant exercise representations, although the effects may be short-term. Additionally, it has been found that activating

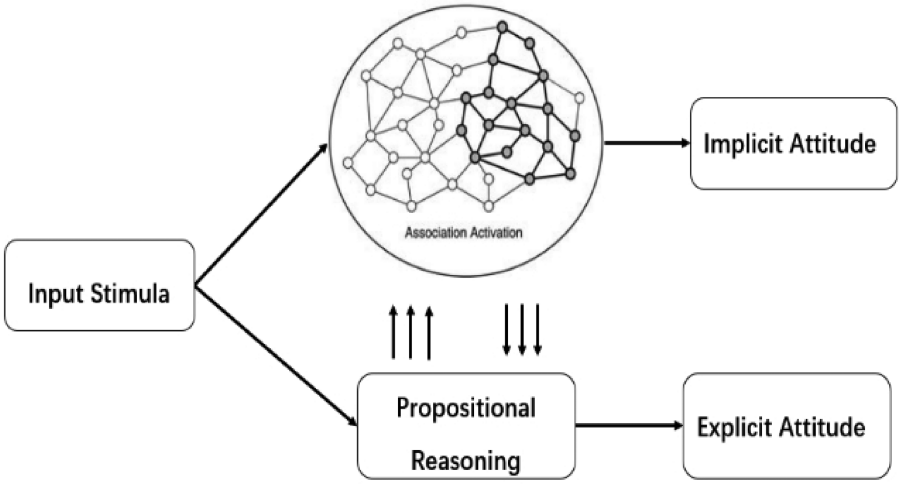

FIGURE 1
Mechanism of action of the associative proposition evaluation model (7).

autobiographical representational memory can enhance physical activity behavior, with representations often serving as motivational incentives for high-level athletes (14). Other studies have explored how representations can enhance physical activity behavior (15), and Dasgupta and Greenwald (16), among others, found that presenting individuals with sample pictures of a different nature could alter their automatically generated implicit cognitive biases. Consequently, a substantial body of research suggests that both implicit and explicit attitudes can be altered through specific techniques.

1.3 Summary of hypotheses and objective

Based on Greenwald and Banaji's (17) implicit social cognition theory and Gawronski and Bodenhausen's (5) APE model, this study aims to assess university students' attitudes toward physical activity and to change their attitudes towards physical activity. First, a questionnaire survey and the Implicit Association Test will be used to analyze the differences in explicit and implicit attitudes towards physical activity among male and female university students with different levels of physical activity. Then, from the university students who participated in the initial tests, those with low levels of physical activity are selected. Using the self-generated information task paradigm of the APE model, the study examines the impact of self-generated information on the implicit and explicit attitudes of university students towards physical activity. Therefore, this study aims to test the following hypotheses:

(H1) University students with high levels of exercise would exhibit more positive implicit and explicit attitudes toward physical activity compared to those with low levels of physical activity. (H2) Male university students would have more positive external and implicit attitudes toward physical activity than female university students. (H3) There would be a relationship between students' explicit and implicit attitudes toward physical activity. (H4) When self-generating a favorite sports star, participants would have more positive implicit and explicit attitudes toward physical activity compared to when generating a disliked sports star. (H5) The effect of self-generated associative information on participants' implicit and explicit attitudes toward physical activity would be influenced by the amount of information. (H6) Participants who self-generated information as like/dislike sports stars would exhibit a tendency to engage in more sports exercise behaviors.

By investigating these hypotheses, the study aimed to contribute to a more comprehensive understanding of the relationship between attitudes, self-generated information, and physical activity among university students. According to the APE model, mental representations of attitudinal goals encompass distinct associations that cannot be simultaneously activated. To enhance the positive affective experience of individuals with low exercise levels and consequently influence their attitude towards physical activity, the activation of exercise-related knowledge associations becomes crucial. In this regard, self-generated associative information, such as generating preferences for liked or disliked sports stars, serves to activate preexisting positive or negative exercise-related knowledge associations stored in memory. This activation leads to the formation of new positive associations that directly impact implicit attitudes, subsequently influencing explicit attitudes. The present study aims to investigate the effects of self-generated like/dislike sports star information on university students' implicit and explicit attitudes towards physical activity, with the intention of enhancing the implicit and explicit attitudes of individuals with low exercise levels. The ultimate objective is to predict and improve exercise levels.

2 Method

First, assessed the exercise levels among university students, and the attitudes towards physical activity selecting those with low physical activity levels. Subsequently, Based on the APE model, it explained changes in implicit and explicit attitudes towards physical activity. Investigated how self-generated associative information (liking/disliking sports stars) and the amount of self-generated information influenced the attitude activation of low-level exercisers. The study found that self-generated positive information could improve both implicit and explicit attitudes towards physical exercise among university students, and further explored the impact of university students' exercise attitudes on their physical activity.

2.1 Participants

A total of 156 general university students from a university in Beijing were recruited for this study. Participants were required to complete the Physical Activity Rating Scale honestly. From the initial sample, 103 participants (male to female ratio of 4:6, age 20.7 ± 1.97 years). Among them, 30% had low levels of exercise, while 70% had high levels of exercise. Among the participants with low levels of exercise, based on the results of the Implicit Association Test, data from 4 participants were excluded due to careless responses and missing answers. This left 66 valid participants (male to female ratio of 3:7, age 20.5 ± 2.03 years) were involved in the self-generated information task. All participants reported no physical or vision-related diseases that could potentially impact their participation. Moreover, all participants voluntarily agreed to take part in the experiment, demonstrated familiarity with computer operations, and had not previously participated in similar experiments. This rigorous screening process aimed to ensure a homogeneous sample of university students with varying levels of exercise and without any confounding health conditions.

2.2 Measures

103 participants used the Physical Activity Rating Scale to measure their level of exercise, the IAT Program to measure implicit attitudes, and the TPB Attitude Scale to measure explicit attitudes towards physical activity. Physical Activity Rating Scale (PARS-3) revised by Liang (18), the exercise volume of the

subjects participating in physical activity in one year was assessed from three aspects: intensity, time and frequency. Exercise volume = intensity × time × frequency. Exercise volume evaluation criteria: ≤19 points for small exercise volume; 20–42 points for moderate exercise volume; ≥43 points for large exercise volume, and two groups of high and low exercise levels are screened out. The reliability of the Physical Activity Rating Scale was 0.82.

This study employed the IAT, which has been widely used in previous research to investigate implicit attitudes (19–21, 34). This test paradigm involves linking physical activity-related conceptual vocabulary and non-physical activity-related conceptual vocabulary with positive and negative attribute words. The IAT test was conducted using a Dell 14-inch LCD color display with a resolution of 1,366 × 768. The experimental program was created using Inquisit 3.0.2 professional IAT software. The test consisted of seven stages, with the target words displayed in green and the attribute words in white. The font used was Arial, and the background was black. The category labels were positioned in the upper left and upper right corners of the screen, while the stimulus words were presented in the center. The participants were seated approximately 40 cm away from the screen. The IAT program followed an evaluation-type design, and the specific procedure is detailed in Table 1.

The TPB Attitude Scale from The Planned Behavior Scale was used to measure the participants' explicit attitudes. The TPB Attitude Scale consists of instrumental and affective attitude measures, including 2 instrumental attitude items (useful-useless, sensible-stupid), 3 affective attitude items (interesting-boring, relaxing-tense, happy-painful) on a seven-point scale. The reliability of the TPB Attitude Scale was 0.74. Assessments that take into account implicit and explicit attitudes may be affected by the order of measurement. After the subjects completed the implicit attitude test, the explicit attitudes were measured (22).

A self-generated information task was employed, using 2 (self-generated associative information: like, dislike sports stars) × 2 (quantity: 2, 7) between-subjects experimental design. The independent variables were the self-generated associative information and its quantity. The dependent variables were the participants' scores on implicit and explicit attitudes towards physical exercise, as well as their behavioral intention scores. Participants ($n = 66$) with low levels of exercise, were randomly assigned to one of the four groups. (1) listing 2 names of sports stars they liked, (2) listing 7 names of sports stars they liked, (3) listing 2 names of sports stars they disliked, and (4) listing 7 names of sports stars they disliked. The distribution of participants in each group was as follows: 17 participants in the 2 names liked group, 16 participants in the 7 names liked group, 17 participants in the 2 names disliked group, and 16 participants in the 7 names disliked group. The specific implementation steps are as follows:

Step 1: Self-generated information task. Participants were instructed to recall and list either 2 or 7 sports stars they liked or disliked. The following guiding phrases were provided:

"Please carefully recall 2 sports stars you like. Please list the names of these 2 sports stars in the space below."

"Please carefully recall 7 sports stars you like. Please list the names of these 7 sports stars in the space below."

"Please carefully recall 2 sports stars you dislike. Please list the names of these 2 sports stars in the space below."

"Please carefully recall 7 sports stars you dislike. Please list the names of these 7 sports stars in the space below."

Step 2: Measurement of implicit attitudes using the Implicit Association Test (IAT).

Step 3: Explicit attitude measure.

Step 4: Measurement of exercise behavior. Participants were presented with a choice between engaging in a cognitive task or skipping rope. They were then given one minute of free skipping.

2.3 Data analysis

SPSS 22.0 was used for statistics and analysis of the results. Descriptive statistics were calculated for parametric variables, including mean values and standard deviations (SD).Paired sample t test and two-way analysis of variance were used. The relationship between the two factors was analyzed using correlation analysis. Data were analyzed using non-parametric statistical tests. Statistical significance was accepted as $p < 0.05$.

3 Results

3.1 Implicit and explicit attitudes towards physical activity

A paired sample *t*-test was conducted to compare the performance on the compatible and incompatible tasks in the evaluative IAT test for implicit attitudes towards physical activity.

TABLE 1 Evaluative IAT.

Step	Task description	Number of trials	Key response	
			Left button	Right button
1	Practice initial concept word identification	20	Physical activity glossary	Non-physical Activity glossary
2	Practice associative attribute word identification	20	Positive	Negative
3	Practice linking task 1	20	Positive + physical activity	Negative + physical activity
4	Formal linkage task 2	40	Positive + physical activity	Negative + physical activity
5	Practice identifying opposite attribute words	20	Negative	Positive
6	Practice opposite linkage task 1	20	Negative + physical activity	Positive + physical activity
7	Formal opposite linkage task 2	40	Negative + physical activity	Positive + physical activity

TABLE 2 Comparison of differences between evaluated IAT compatible and incompatible task response times.

	Different tasks	*M*	*SD*	*t*	*p*
	Compatible	846.74	203.48		
Evaluated IAT T				−18.02	0.00
	Incompatible	1,276.98	336.22		

The relevant statistical results are presented in Table 2. The results presented in Table 2 indicate a highly significant implicit effect of the evaluative IAT test ($t = -18.02$, $df = 102$, $p < 0.01$). These findings demonstrate that university students tend to associate physical exercise with positive attributes and hold a positive attitude towards physical exercise. Moreover, the implicit attitudes towards physical exercise among university students with high exercise levels are more positive compared to those with low exercise levels. This pattern of results provides clear support for Hypothesis 1. To further explore the relationship between exercise level, gender, and the implicit test of the evaluative IAT, a two-way ANOVA was conducted. Exercise level and gender were used as independent variables, while the evaluative IAT served as the dependent variable. The means for each condition are presented in Table 3.

The ANOVA results showed (see Table 4) that the main effect of exercise level was significant, $F\ (1, 99) = 30.16$, $p < 0.05$, $\eta^2 = 0.23$; the main effect of gender was marginally significant, $F\ (1, 99) = 3.34$, $p > 0.05$, $\eta^2 = 0.03$; the interaction between exercise level and gender was not significant, $F\ (1, 99) = 0.12$, $p > 0.05$, $\eta^2 = 0.02$. The results show that university students with high exercise level had higher implicit attitudes in evaluative IAT than those with low exercise levels, and that university students of both genders had significant margins in the Evaluative IAT.

A two-way ANOVA was conducted with high and low exercise levels and different genders of university students as independent variables and explicit attitudes as dependent variables. Means are displayed in Table 5. The results of the ANOVA (Table 6) showed that the main effect of exercise level was significant, $F\ (1, 99) = 21.82$, $p < 0.01$, $\eta^2 = 0.18$; the main effect of gender was significant, $F\ (1, 99) = 4.53$, $p < 0.05$, $\eta^2 = 0.04$; the interaction of exercise level and gender was not significant, $F\ (1, 99) = 0.47$, $p > 0.05$, $\eta^2 = 0.01$. The results indicate that there is a significant difference between high and low exercise level university students in terms of their externalised attitudes, with higher exercise level university students ($M_{male} = 6.62$, $M_{female} = 5.91$) having higher externalised attitudes than low exercise level university students ($M_{male} = 5.28$, $M_{famale} = 4.92$). This pattern of results clearly supported H1. There was a significant difference between the gender of the university students in terms of their explicit attitudes, with male university students having more positive exogenous attitudes than females. This pattern of results clearly supported H2.

A correlation analysis of the implicit and explicit attitudes towards physical activity among university students (see Table 7) showed that there was a significant positive correlation between the explicit attitudes and the evaluative IAT ($r = 0.25$). This indicates that implicit and explicit attitudes are significantly correlated. Hofmann et al. (36) meta-analysis of 126 studies with 53 different contents showed a correlation of 0.24 between implicit association measures and explicit measures. Nosek (37) analysed a large sample of data obtained from a web-based survey and found that the correlation coefficient between implicit and explicit attitudes fluctuated in the range of 0.01–0.62. This also demonstrates that implicit attitudes are not completely unconscious in the APE model and that there is a relationship between implicit and explicit attitudes. The results of the correlation clearly supported H3.

TABLE 3 Descriptive statistics of high and low exercise levels and gender-specific university students in evaluative IAT scores.

Exercise level	Gender	*M*	*SD*	*n*
High	Male	551.96	309.52	21
	Female	657.59	150.65	12
Low	Male	302.58	132.58	19
	Female	374.16	205.11	51

TABLE 4 Analysis of variance (ANOVA) for high and low exercise level and gender-specific university students in evaluative IAT scores.

Source of variation	*df*	*F*	*p*	η^2
Exercise level	1	30.16	0.00	0.23
Gender	1	3.34	0.07	0.03
Exercise level × gender	1	0.12	0.73	0.02

TABLE 5 Descriptive statistics on explicit attitude scores of high and low exercise levels and male and female university students.

Exercise level	Gender	*M*	*SD*	*n*
High	Male	6.62	0.55	21
	Female	5.91	1.01	12
Low	Male	5.28	0.79	19
	Female	4.92	1.37	51

TABLE 6 Analysis of variance (ANOVA) for high and low exercise level and gender-specific university students' explicit attitude scores.

Source of variation	*df*	*F*	*p*	η^2
Exercise level	1	21.82	0.00	0.18
Gender	1	4.53	0.03	0.04
Exercise level × gender	1	0.47	0.49	0.01

3.2 Self-generated associative information

A two-way ANOVA was conducted using the generation of associative information and quantity as independent variables and the score of implicit attitudes as dependent variables

TABLE 7 Correlation analysis between indicators of implicit and explicit tests.

	Evaluated IAT	External attitude
Evaluated IAT	1	
External attitude	0.25	1

TABLE 8 Descriptive statistics of self-generated associative information and quantity of implicit attitude scores.

Associated Information	Quantity	*M*	*SD*	*n*
Like	2 pcs	484.44	157.87	17
	7 pcs	346.78	159.84	17
Dislike	2 pcs	321.26	124.95	16
	7 pcs	389.90	132.75	16

TABLE 9 Analysis of variance for self-generated associative information and quantity of implicit attitude scores.

Source of variation	*df*	*F*	*p*	η^2
Associated information	1	4.41	0.04	0.07
Quantity	1	0.30	0.59	0.01
Associated Information × quantity	1	6.08	0.01	0.09

TABLE 10 Descriptive statistics of self-generated associative information and quantity of explicit attitude scores.

Associated information	Quantity	*M*	*SD*	*n*
Like	2 pcs	4.96	0.96	17
	7 pcs	5.52	1.01	17
Dislike	2 pcs	4.72	1.25	16
	7 pcs	4.25	0.92	16

TABLE 11 ANOVA of self-generated association information and quantity in explicit attitude scores.

Source of variation	*df*	*F*	*p*	η^2
Associated information	1	9.37	0.00	0.12
Quantity	1	0.03	0.86	0.00
Associated information × quantity	1	4.00	0.05	0.06

(Descriptive results are shown in Table 8). The results of the ANOVA revealed (see Table 9) that the main effect of subjects' self-generated associative information was significant F (1, 62) = 4.41, $p < 0.05$, $\eta^2 = 0.07$, and that subjects' implicit attitudes towards physical activity were significantly higher when they self-generated information about liking sports stars than in the self-generated disliked sports stars condition. The results of the correlation clearly supported H4. The main effect of the quantity of self-generated associative messages by subjects was not significant F (1, 62) = 0.30, $p > 0.05$, $\eta^2 = 0.01$, and the interaction between generated associative messages and quantity of implicit attitudes was significant F (1, 62) = 6.08, $p < 0.05$, $\eta^2 = 0.09$ (see Figure 2).

A simple effects test showed that there was a significant difference between liked/disliked sports stars on implicit attitudes towards physical activity when the self-generated associative information was 2, F (1, 62) = 10.4, $p < 0.05$; the effect on implicit attitudes towards physical activity when liked/disliked sports stars did not reach a significance level when the self-generated associative information was 7, F(1, 62) = 0.07, $p > 0.05$. This indicates that the generation of 2 like sports stars had a positive effect on the implicit attitude towards physical activity among university students. The results of the correlation clearly supported H5.

A two-way ANOVA was conducted with self-generated associative information and quantity as the independent variables and scores of explicit attitudes towards physical activity as the dependent variables (Descriptive results are shown in Table 10). The results of the ANOVA showed (see Table 11) that the main effect of the subject generating associative information was significant F (1, 62) = 9.37, $p < 0.01$, $\eta^2 = 0.12$, and that the subject's explicit attitude towards physical activity was significantly higher in the self-generated like sports stars than in the self-generated dislike sports stars condition ($M_{\text{Like2}} = 4.96$, $M_{\text{Dislike2}} = 4.72$;

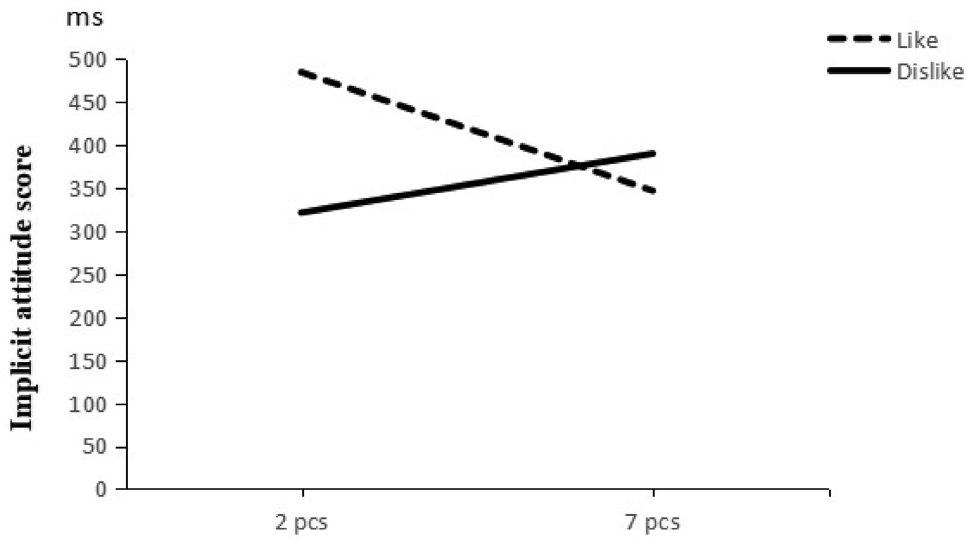

FIGURE 2
Interaction between self-generated associative information and quantity on implicit attitudes.

TABLE 12 Chi-square analysis of self-generated information and behavioral choices.

Self-generated information	Test skipping rope		Total
Like sports stars	10 (13.8)	21 (17.2)	31
Dislike sports stars	18 (14.2)	14 (17.8)	32
Total	28	35	63

$M_{Like7} = 5.52$, $M_{Dislike2} = 4.25$), see Table 12, clearly supported H4. The main effect of the quantity of associative messages generated by the subjects was not significant $F\ (1,\ 62) = 0.30$, $p > 0.05$, $\eta^2 = 0.00$, and the interaction between the quantity of associative messages generated and the number of explicit attitudes was significant $F\ (1,\ 62) = 6.08$, $p < 0.05$, $\eta^2 = 0.06$ (see Figure 3).

A simple effects test showed that subjects had a significant difference between liked/disliked sports stars in their explicit attitudes toward physical activity when generating seven associative messages $F\ (1,\ 62) = 12.2$, $p < 0.05$; liked/disliked sports stars did not reach a significance level in their explicit attitudes towards physical activity when generating two associative messages $F\ (1,\ 62) = 0.43$, $p > 0.05$. This indicates that the self-generation of 7 like sports stars had a positive effect on the explicit attitude towards physical activity. The results of the correlation clearly supported H5.

3.3 Physical activity

After initiating the attitudes towards physical activity of self-generating preferences for like/dislike sports stars, the participants were given two options: to choose to continue with the test or engage in one minute of free skipping. Using self-generated information (like/dislike sports stars), the participants' behavioral choices (skipping rope/test) were subjected to a chi-square test (see Table 12). The results of the chi-square test indicated $\chi^2 = 3.67$, $p < 0.05$. This suggests that self-generated sports stars information is associated with the behavior of skipping rope, and participants are more likely to choose skipping rope as their preferred activity. The results of the correlation clearly supported H6.

4 Discussion

The current study aimed to promote physical activity among university students by changing their attitudes towards physical activity through self-generated information. In measuring university students' attitudes towards physical activity, the research findings indicate a significant impact of university students' implicit attitudes towards physical exercise as measured by the IAT. Specifically, there is a stronger association between physical exercise vocabulary and positive attributes, leading to faster responses. Moreover, university students with high exercise levels demonstrate more positive implicit and explicit attitudes towards physical exercise compared to those with low exercise levels. These results align with previous studies, such as the review conducted by Rebar et al. (11), which highlighted the correlational nature of the evidence linking physical activity and implicit attitudes.Additionally, male participants exhibit more positive explicit attitudes towards physical exercise compared to females. These differences may stem from traditional concepts and social stereotypes, with males placing greater emphasis on

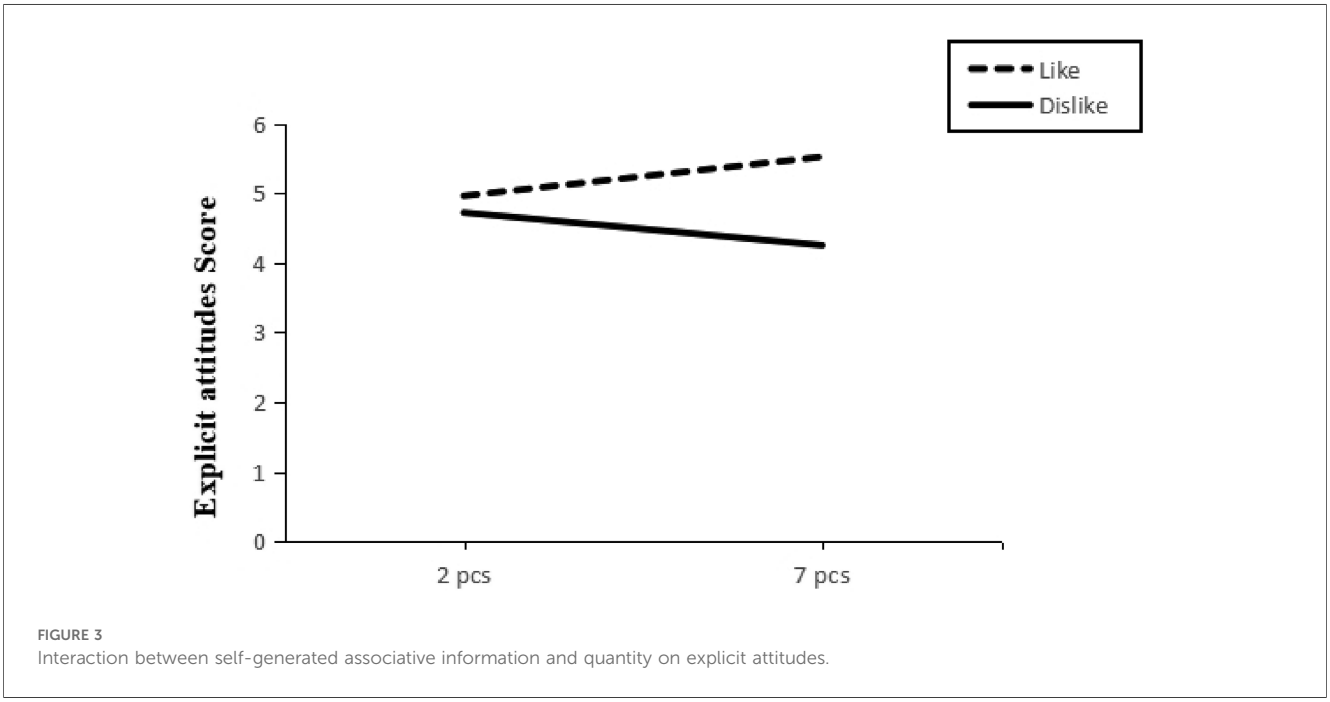

FIGURE 3
Interaction between self-generated associative information and quantity on explicit attitudes.

physical attributes like body shape, strength, and muscles. Such factors contribute to variations in attitudes towards physical exercise between genders. Importantly, there is a significant correlation between university students' IAT scores and their explicit attitudes ($r = 0.25$). This finding aligns with Hofmann, Gawronski, and Schmitt's (2005) meta-analysis, which reviewed 126 research reports covering a wide range of topics. The meta-analysis indicated that the correlation between implicit association measurement and explicit attitudes fluctuates between 0.01 and 0.62. This result provides a fresh perspective for investigating the relationship between implicit and explicit attitudes and supports the notion that implicit attitudes in the APE model are not entirely unconscious, but rather interconnected with explicit attitudes. The formation of an exercise habit is a process that transitions from conscious effort to unconscious routine. At the beginning of an physical activity, conscious effort and attention are required. After maintaining it for a period of time, it can eventually become a habit, at which point the need for conscious effort and attention will decrease (23).

Implicit attitudes were previously believed to be stable and socially ingrained evaluative representations (24, 25). However, research has shown that situational factors can influence implicit attitudes (5). Conroy and Berry (26) consider automated assessments of exercise and physical activity as "potentially modifiable targets" for specific interventions. The findings of the current study demonstrate that self-generated associative information related to physical activity, such as liked or disliked sports stars, acts as a situational factor that influences both implicit and explicit attitudes towards physical activity.

In this study, self-generated associative information about sports stars effectively enhanced positive or negative associations in the participants' memory systems regarding implicit attitudes towards physical activity, resulting in changes in implicit attitudes in subsequent IAT tests among university students. Recent arguments propose that associative activation can reconstruct implicit attitudes (27). The activation of self-generated liked/disliked sports star information induced specific positive/negative association patterns with physical activity, influencing both implicit and explicit attitudes towards physical activity. This suggests that contextual cues elicit distinct patterns of associative activation and that self-generated associative information can influence implicit attitudes (28, 29). Consequently, implicit attitudes can be modified through self-generated associative information.

Furthermore, researchers have examined the impact of celebrity endorsements on attitudes and product choices. Moran et al. (30) found that relational information has a stronger impact on non-automatic stereotypes compared to automatic stereotypes. Craeynest et al. (31) found that changes in implicit attitudes toward food and exercise had some small impact on obesity treatment in adolescents. A meta-analysis provides evidence that implicit attitudes toward physical activity are positively associated with physical activity in adults to a small degree (12). Based on the APE research on attitudes, Janiszewski Kuo and Tavassoli (32) suggest that attention should be focused on capturing consumer attention and enhancing consumers' cognitive association with the brand (athlete and product). Studies have also indicated that implicit and explicit attitudes can predict health-related behaviors (33). The current study supports the research hypothesis that self-generated information can enhance immediate exercise behavior.

5 Limitations

In this study, the influence of attitude on immediate exercise behavior was found to be significant. However, further investigation is needed to explore the lasting effects of attitude on exercise behavior, with the goal of fostering long-term engagement in physical exercise and forming a healthy exercise habit. the study only provided an initiation of attitudes, and the sustained effect of this initiation needs to be verified. Future studies could expand the selection of participants for the study by choosing different regions, different universities, or different age groups as experimental participants.

6 Conclusion

Attitudes are malleable, and the APE model finds support in the domain of physical activity, where associative processing can influence both implicit and explicit attitudes towards physical activity. The study reveals that university students hold positive implicit and explicit attitudes towards physical activity, with those having a high exercise level exhibiting more positive implicit and explicit attitudes compared to those with a low exercise level. Moreover, male university students demonstrate more positive explicit attitudes towards physical activity than their female counterparts. The introduction of self-generated information regarding their favorite sports stars further enhances university students' implicit and explicit attitudes towards physical activity. Notably, changes in attitude exhibit a certain predictive effect on exercise behavior and can temporarily foster increased engagement in physical activity, which helps promote university students' active participation in 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 Academic Division of Sports and Health, Beijing Sport 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. The manuscript presents research on animals that do not require ethical approval for their study.

Author contributions

JN: Visualization, Data curation, Formal Analysis, Writing – review & editing.

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Conflict of interest

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

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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Bartłomiej Gąsienica-Walczak,
Academy of Applied Sciences in Nowy Targ, Poland
Giuseppe Battaglia,
University of Palermo, Italy
Adam Prokopczyk,
Poznan University of Physical Education, Poland

*CORRESPONDENCE
Hengchan Yin
✉ yinhengchan1963@163.com
Lei Cui
✉ cuilei@bnu.edu.cn

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Time-course effects of exercise intervention on executive function in adolescents with obesity

Lingling Hu[1,2], Qiqi Shen[1], Hengchan Yin[1]* and Lei Cui[1]*

[1]College of P.E. and Sports, Beijing Normal University, Beijing, China, [2]Student Affairs Office, China Conservatory of Music, Beijing, China

Objective: This study was to investigate the developmental characteristics of executive function (EF) in obese adolescents and the time-course effects of a 14-week exercise intervention combining aerobic exercise and resistance training on EF in this population.

Methods: The experimental group of 28 obese junior high school students participated in the exercise intervention combining aerobic exercise and resistance training, while the control group of 24 healthy weight junior high school students engaged in the regular recess exercise. EF, including inhibition, working memory, and cognitive flexibility, was assessed 1 week prior to the exercise intervention and at 12 and 14 weeks post-intervention. Changes in EF sub-functions in both groups at different time points during the exercise intervention were analyzed.

Results: The findings revealed that obese junior high school students exhibited lower levels of inhibition ($p = 0.003$, Cohen's $d = 0.848$) and cognitive flexibility ($p = 0.013$, Cohen's $d = 0.706$) compared to their healthy weight peers. The exercise intervention combining aerobic exercise and resistance training led to significant improvements in EF among obese junior high school students, with inhibition ($p < 0.01$, Cohen's $d = 0.713$; $p = 0.003$, Cohen's $d = 0.683$) and cognitive flexibility ($p = 0.001$, Cohen's $d = 0.797$; $p < 0.01$, Cohen's $d = 0.890$) showing significant improvement at 12 and 14 weeks post-intervention, and working memory demonstrating significant improvement at 14 weeks ($p = 0.004$, Cohen's $d = 0.710$). No significant differences were observed in EF over time in healthy weight junior high school students.

Conclusion: Obese adolescents had impaired EF, as evidenced by low levels of the inhibition and cognitive flexibility compared to healthy weight adolescents. The exercise intervention combining aerobic exercise and resistance training had a positive effect on EF of obese adolescents. The time-course effects of the intervention on improvements in inhibition, working memory, and cognitive flexibility varied with intervention duration in obese adolescents, with significant changes in inhibition and cognitive flexibility observed at 12 weeks and significant changes in working memory at 14 weeks.

KEYWORDS

obese adolescents, executive functions, exercise, inhibition, working memory, cognitive flexibility

1 Introduction

Globally, there is a persistent public health concern regarding the high prevalence of overweight and obesity (Douglas et al., 2019; Taghizadeh and Farhangi, 2020; Hestbaek et al., 2021; Karampatsou et al., 2021; Clarke et al., 2022). Adolescents who are obese face adverse effects on their physical fitness and are at an elevated risk of developing chronic conditions such as diabetes and hypertension (Disse and Zimmer, 2014; Gao et al., 2022). Additionally, obesity has been found to have a negative impact on the cognitive function of adolescents (Smith et al., 2011; Bocarsly et al., 2015; Wang et al., 2016; Meo et al., 2019).

One crucial aspect of cognitive function is executive function (EF), which encompasses higher-level cognitive processes that regulate and manage various fundamental cognitive functions during the execution of complex cognitive tasks. EF comprises three sub-functions: inhibition, working memory and cognitive flexibility (Friedman et al., 2006; Diamond, 2012; Chen et al., 2019). Research indicated that obese adolescents exhibit poorer inhibition in EF compared to their healthy weight peers (Yi et al., 2015; Kittel et al., 2017; Mamrot and Hanć, 2019). Therefore, it is imperative to investigate effective strategies to enhance the EF of obese adolescents.

Moreover, prior research has indicated that exercise intervention can enhance physical fitness, motor proficiency, and academic achievement in adolescents with and without disabilities (Davis et al., 2011; Battaglia et al., 2019). These studies have also shown that exercise intervention can enhance EF in both typically developing adolescents and those disabilities who exhibit deficits in EF (Davis et al., 2011; O'Malley, 2011; Audiffren and André, 2019; Lind et al., 2019; Mehren et al., 2019; Schwarck et al., 2019). However, there was a lack of research on exercise intervention targeting EF in obese adolescents, and the progression of changes over time remained unclear. Therefore, this study aimed to investigate the developmental characteristics of EF in obese junior high school students. By focusing on the characteristics of EF, the study implemented a 14-week exercise intervention combining aerobic exercise and resistance training. The exercise intervention was designed based on three key pathways for enhancing EF through exercise: action characteristics, exercise intensity, and exercise scenarios (Pan et al., 2016). The aim of the study was to investigate the effects of exercise intervention on the EF of obese junior high school students, as well as the time-course effects, in order to develop an efficient exercise intervention regimen for enhancing the EF of obese adolescents. The objective of the research was to establish a theoretical foundation and practical guidance for utilizing exercise to enhance the physical and mental well-being of this population. The study hypothesized that obese adolescents exhibit lower EF levels compared to their healthy weight peers, and that exercise intervention can enhance the different sub-functions of EF in obese adolescents, with the effectiveness of improvement varying over time.

2 Materials and methods

2.1 Study design

A hybrid experimental design involving 2 groups (experimental group, control group) × 3 time points (pretest, 12 weeks, 14 weeks) was implemented in this study (Pan et al., 2016).

The experimental group consisted of obese junior high school students who performed an exercise intervention combining aerobic exercise and resistance training. The control group consisted of junior high school students of healthy weight who performed regular recess exercises.

The exercise intervention was administered by professional physical education instructors. Several prior research studies have demonstrated that a 12-week exercise intervention can enhance EF to different extents (Liu, 2017; Meng, 2021; He, 2022). This study aimed to investigate whether a longer duration of exercise intervention can lead to greater improvements in EF. To achieve this, the length of the exercise intervention was extended, and assessments of EF were conducted at both the 12-week and 14-week marks of the intervention period.

2.2 Participants

A priori sample size estimation was conducted using G*Power version 3.1.9.7 (Kang, 2021), with an effect size f of 0.25, α as 0.05, group as 2, number of measures as 2, the sample size was 28.

The obese junior high school students included in this study were selected based on specific criteria. These criteria were: (1) Body Mass Index (BMI): BMI = weight (kg)/height (m)^2. BMI screening according to WS/T 586–2018 Screening for overweight and obesity among school-age children and adolescents (National Health and Family Planning Commission, 2018), that is, males were eligible for inclusion if they had a BMI greater than 25.2 kg/m^2 at age 13 years and 25.7 kg/m^2 at age 13.5 years, and females were eligible for inclusion if they had a BMI greater than 25.0 kg/m^2 at age 13 years and 25.6 kg/m^2 at age 13.5 years. (2) Body Fat Ratio (BFR): BFR was measured by Bioelectrical Impedance Analysis (BIA) using a Body Composition Analyzer (Brand: TANITA, Model: MC-980MA), and according to WHO guidelines (WHO Expert Committee, 1995; Chusyd et al., 2016; Tomassoni et al., 2020; Iłowiecka et al., 2021), a BFR greater than 25% for males and 35% for females was considered eligible for inclusion. (3) All participants were aged between 13 and 14 years, of normal intelligence, without a history of psychiatric or genetic disorders. They willingly volunteered for the study, provided written informed consent, and their parents were informed and consented to their participation.

In this study, cluster sampling methodology was employed to select participants. Specifically, 28 obese junior high school students were identified from a pool of 170 students, resulting in a detection rate of 16.5%. Additionally, 24 junior high school students with healthy BMI and BFR were chosen randomly to serve as the control group. The group of the experiment was double-blind, ensuring that both the subjects and the individuals administering the exercise intervention were unaware of the group assignments.

The study was carried out following the guidelines outlined in the Declaration of Helsinki, received approval from the Ethics Committee, adhered to the Standards of Ethics in Sport and Exercise Science Research, and was undertaken in partnership with the Laboratory School. The study protocol was registered with the Chinese Clinical Trial Registry at https://www.chictr.org.cn/.

2.3 Materials

The EF was assessed using the E-prime 2.0 system on a computer (Chen et al., 2011a,b). Participants were instructed to provide prompt and precise responses in each task, emphasizing the attainment of

proficiency before progressing to the formal assessment. EF evaluations were conducted at three specific intervals: 1 week pre-intervention, 12 weeks post-intervention, and 14 weeks post-intervention. The collection of EF test data was organized by members of the research team.

In the Flanker task, participants were presented with two types of conditions: consistent conditions, where all letters on the screen are the same (e.g., "FFFFF"), and inconsistent conditions, where the middle letter was different from the others (e.g., "FFLFF"), as shown in Figure 1. Each condition was displayed for 1,000 ms with an intermediate interval of 500 ms "+." The conditions were randomly presented with equal probability during the test, which includes 12 practice trials followed by 48 formal judgments. Test scores were calculated as the mean response time (RT) for inconsistent conditions minus that for consistent conditions, with a smaller difference indicating better inhibition performance.

In the 1-back task, participants were exposed to a series of 26 English letters displayed on a screen. Each letter was shown for a duration of 2,000 ms, with a 3,000 ms interval between consecutive letters. The task required subjects to determine if the current letter matched the preceding one and respond accordingly using a designated key, as illustrated in Figure 2. Prior to the main data collection phase, participants underwent 12 practice trials. The formal task comprised 25 judgment trials. Performance on the task was assessed based on the average RT, with shorter times indicating better working memory capacity.

In the More-odd shifting task, participants were exposed to numerical stimuli, with one number displayed on each screen. Each number was shown for 2,000 ms, with a 3,000 ms interval between different digits. The test comprised three distinct stages. The initial stage involved the presentation of black numbers to assess the relationship between the number and the magnitude of 5. Subsequently, green numbers were displayed in the second stage to evaluate the parity of the numbers (odd or even). In the final stage, a mix of green and black numbers were randomly presented, with participants required to judge magnitude when black numbers appeared and parity when green numbers were shown, as illustrated in Figure 3. The first and second stages each included 8 practice trials and 16 formal judgments, while the third stage encompassed 16 practice trials and 32 formal judgments. Cognitive flexibility was evaluated by measuring the difference in RT, calculated as the average RT of the third stage minus the average RT of the first and second stages. Smaller differences indicated better cognitive flexibility.

2.4 Procedure

Exercise in the experimental and control groups took place at the same time. The experimental group participated in a 40-min exercise intervention combining aerobic exercise and resistance training, while the control group participated in a 40-min regular recess exercises. Both groups engaged in exercise activities during the 50-min morning school recess period. The exercise intervention was centrally administered from September to December.

The multi-path theory, as posited by our research team in the previous period, suggested that the beneficial impact of exercise intervention on EF development can be realized through three pathways (Pan et al., 2016): action characteristics, exercise intensity and exercise scenarios. Action characteristics refer to the technical characteristics of the exercise program, such as the complexity, novelty and relevance of the actions involved. Actions that were intricate, innovative, and purposeful necessitate continual adjustment and adaptation to external stimuli, thereby engaging EF in the brain. This engagement was further enhanced through repetitive training. Exercise intensity encompassed varying levels of exertion, including low, moderate, and high intensity. Research indicated that different intensities of exercise both can enhance EF, with moderate intensity exercise demonstrating the most favorable outcomes (Chen et al., 2014). Exercise scenarios referred to the instructional and learning environment in which individuals engage in physical activity. Movement learning was most effective when situated within a specific context, and the sub-components of EF can be strengthened through the implementation of cooperative, multi-memory point, multi-tasking, and problem-based scenarios.

Based on the above, in the development of an exercise intervention for obese junior high school students, in terms of action characteristics, the difficulty of the actions was gradually increased according to the subjects' mastery of each motor skill, from single actions to combined actions, from simple to complex actions, and from familiar to unfamiliar actions. In terms of exercise intensity, a subset of participants wore Polar heart rate monitors during each exercise intervention, with average heart rates recorded at specific intervals to ensure moderate intensity levels were maintained. Furthermore, exercise scenarios were tailored to include cooperative, multi-memory point, multi-tasking, and problematic challenges aligned with participants' preferences, gradually escalating cognitive demands to sustain engagement and enhance EF.

The 14-week exercise intervention program consisted of the following components: (1) Exercise frequency: participants engaged in physical activity 4 times per week. (2) Exercise intensity: participants exercised at a moderate intensity, calculated as (220 minus age) multiplied by 60–69%. (3) Duration of each exercise session: 40 min per session, comprising 5 min of warm-up, 20 min of aerobic exercise, 10 min of resistance training, and 5 min of relaxation exercises. (4) Type of exercise: the intervention included a combination of aerobic exercise and resistance training, with aerobic exercise being the primary focus and resistance training serving as a supplementary component. Aerobic activities included pattern running, aerobic

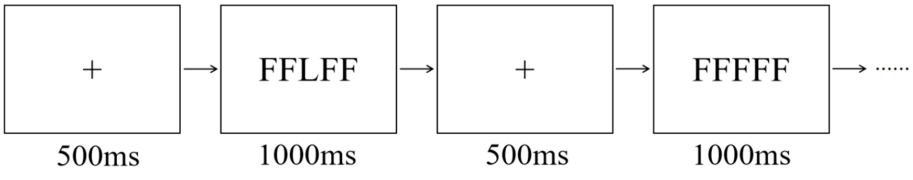

FIGURE 1
Flanker task.

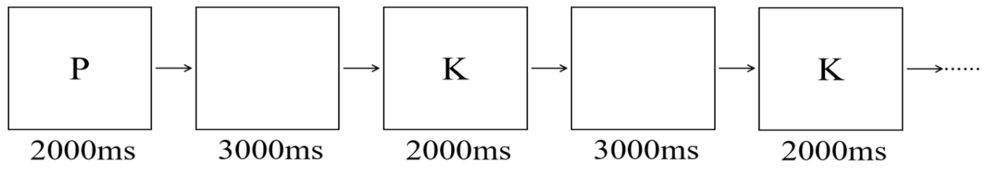

FIGURE 2
1-back task.

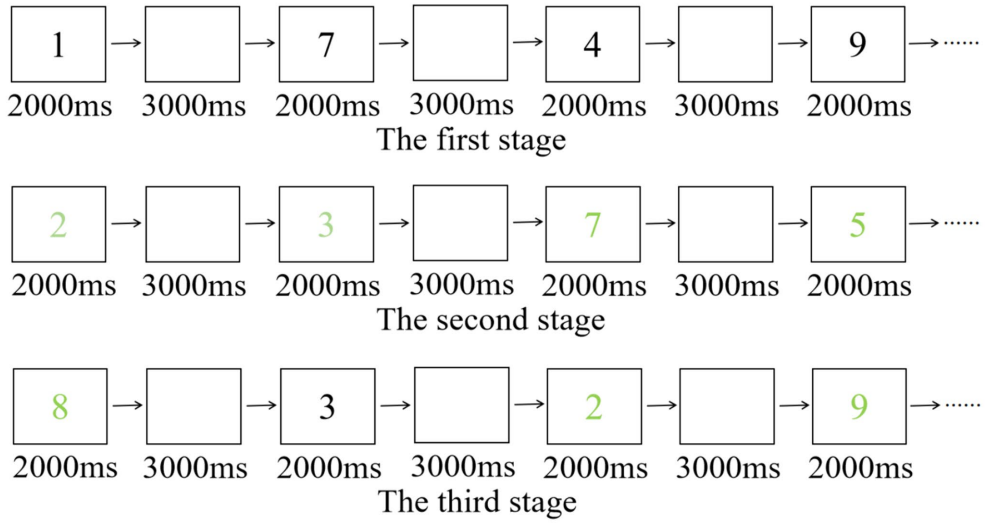

FIGURE 3
More-odd shifting task.

games, and rope ladder training, while resistance training focused on exercises utilizing one's own body weight to target strength development in the upper limbs, lower limbs, and core muscles.

2.5 Data analysis

SPSS 25.0 (SPSS Inc., Chicago, IL, United States) was used to process and analyze the data, the Independent-samples T test was used to developmentally characterize the EF, BMI and BFR of obese and healthy weight junior high school students, and the repeated-measures ANOVA was used to analyze the separate and interactive effects of two factors of group and time, with statistical analysis significant at $p \leq 0.05$. Calculations of "Cohen's effect size" and "post-hoc power analysis" using G*Power version 3.1.9.7 (Kang, 2021), considering α of 0.05, two groups, and three measurement points.

3 Results

3.1 Monitoring of exercise intensity

In order to accurately control the exercise intensity, 4 obese junior high school students were randomly selected in this study to wear Polar meter to monitor heart rate. Specific methods: 2 male and 2 female students were randomly selected, and 5 heart rate measurements were taken during each exercise intervention, namely: during the quiet time before the intervention, the 10th minute, the 20th minute, the 30th minute, and the 40th minute, and the exercise intensity was monitored according to the average heart rate. As shown in Figure 4, the average heart rate of the 4 randomly selected obese junior high school students in the experimental group during the exercise intervention was 134 beats/min, which reached about 65% of their maximum heart rate; as shown in Figure 5, the overall average heart rate of the 4 randomly selected obese junior high school students during each intervention ranged from 129 to 137 beats/min, which reached the expected moderate intensity of the exercise intervention.

3.2 Developmental characteristics of EF in obese junior high school students

To investigate the developmental characteristics of EF in obese junior high school students, pretest data on EF performanced in obese and healthy weight junior high school students were analyzed using Independent-samples *T*-tests. The results revealed that obese junior high school students had longer average RT for EF tasks compared to their healthy weight peers. Specifically, the RT for inhibition in obese junior high school students was significantly higher [$t_{(50)} = 3.069$, $p = 0.003$, Cohen's $d = 0.848$] than in healthy weight peers. Additionally,

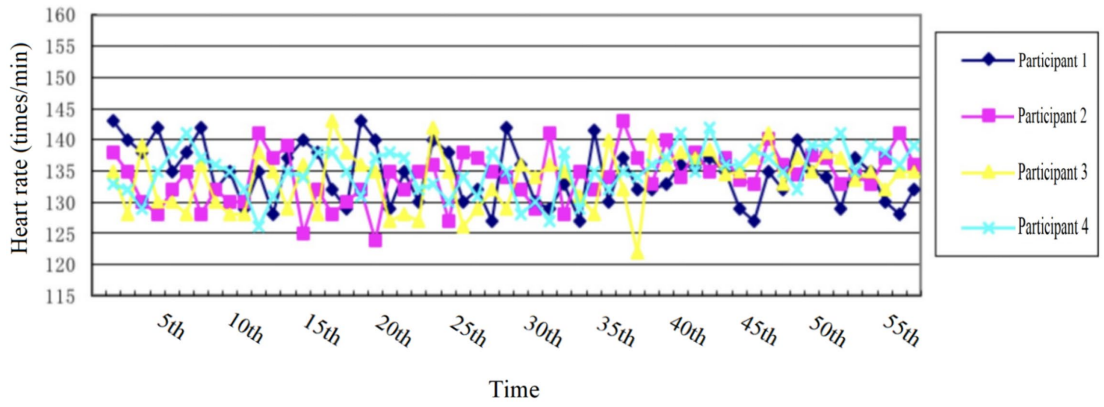

FIGURE 4
The monitoring figure of the individual average heart rate per activity of 4 obese junior high school students in the experimental group.

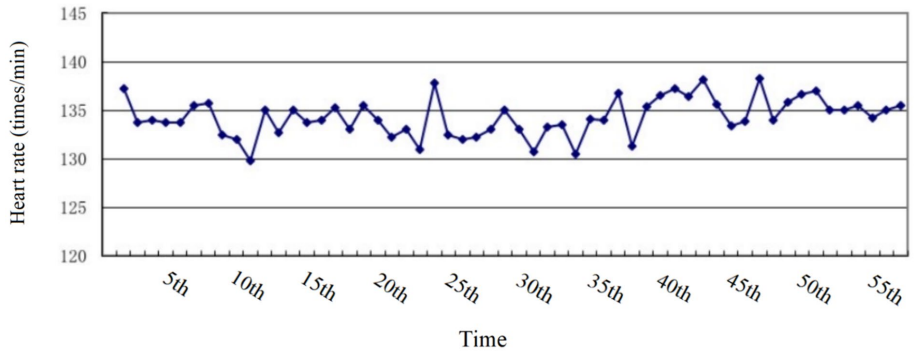

FIGURE 5
The monitoring figure of the overall average heart rate per activity of 4 obese junior high school students in the experimental group.

the RT of cognitive flexibility in obese junior high school students was also significantly higher [$t_{(50)} = 2.600$, $p = 0.013$, Cohen's $d = 0.706$] than in healthy weight peers. However, no significant difference was observed in working memory [$t_{(50)} = 1.047$, $p = 0.300$, Cohen's $d = 0.292$]. These results indicated that obese junior high school students may have lower EF levels than their healthy weight peers, particularly in the areas of inhibition and cognitive flexibility (see Table 1).

3.3 Effects of exercise intervention on EF in obese junior high school students and characteristics of time-course changes

3.3.1 Results of inhibition

The results revealed that the main effect of time on inhibition was significant [$F_{(2,100)} = 5.181$, $p = 0.01$, $\eta^2_p = 0.094$], indicating a trend of change in inhibition over time. The main effect of group on inhibition was significant [$F_{(1,50)} = 5.203$, $p = 0.027$, $\eta^2_p = 0.094$], indicating a significant difference in inhibition between the experimental and control groups. The interaction effect of time * group was also significant [$F_{(2,100)} = 3.848$, $p = 0.03$, $\eta^2_p = 0.071$], indicating a significant difference in the change in inhibition between the experimental and control groups at different time points (see Table 2).

A subsequent analysis of simple effects was conducted, and the following results are shown in Figure 6.

There were significant differences in inhibition at different time points in the experimental group [$F_{(2,49)} = 10.998$, $p < 0.01$, $\eta^2_p = 0.310$]. The inhibition of the experimental group at 12 [$t_{(27)} = 3.774$, $p < 0.01$, Cohen's $d = 0.713$] and 14 weeks [$t_{(27)} = 3.613$, $p = 0.003$, Cohen's $d = 0.683$] were significantly better than the pretest, but there was no significant difference between 12 and 14 weeks [$t_{(27)} = 0.327$, $p = 0.99$, Cohen's $d = 0.153$]. The time-course effect of inhibition showed that 14 and 12 weeks > pretest. That is, the 14-week exercise intervention combining aerobic exercise and resistance training could improve the inhibition of obese junior high school students, and the effect remained stable with the increase in exercise intervention time. Conversely, no significant differences in inhibition were observed across the three time points in the control group [$F_{(2,49)} = 0.045$, $p = 0.956$, $\eta^2_p = 0.002$].

There was a significant difference between obese and healthy weight junior high school students in inhibition at pretest [$F_{(1,50)} = 9.416$, $p = 0.003$, $\eta^2_p = 0.158$], and there was no significant difference in inhibition at 12 [$F_{(1,50)} = 0.883$, $p = 0.352$, $\eta^2_p = 0.017$] or 14 weeks [$F_{(1,50)} = 0.444$, $p = 0.508$, $\eta^2_p = 0.009$]. That is, before the exercise intervention, the inhibition of healthy weight junior high school students was better than that of obese peers. After the exercise intervention, the inhibition of obese junior high school students

TABLE 1 Results of the Independent-samples *T*-test for developmental characteristics of EF in obese and healthy weight junior high school students (M ± SD).

EF	Obese junior high school students	Healthy weight junior high school students	*t*	*p*	Cohen's *d*
Inhibition	24.38 ± 13.79	11.57 ± 16.33	3.069	0.003**	0.848
Working memory	826.21 ± 223.26	762.57 ± 212.71	1.047	0.300	0.292
Cognitive flexibility	473.63 ± 190.24	367.91 ± 93.08	2.600	0.013*	0.706

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

TABLE 2 ANOVA results on the effect of exercise intervention on inhibition in obese junior high school students.

Interaction effect	Type III sum of squares	df	Mean square	*F*	*p*	η^2_p
Group	1393.593	1	1393.593	5.203	0.027*	0.094
Time	1215.521	2	693.719	5.181	0.01**	0.094
Time * group	902.922	2	515.314	3.848	0.03*	0.071

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

aligned with that of healthy weight peers across all assessment time points.

A *post hoc* power analysis was conducted using G*Power version 3.1.9.7 (Kang, 2021), with an effect size *f* of 0.276 (partial η^2 as 0.071), α as 0.05, group as 2, number of measurements as 3, and correlation as 0.228. Within our selected total sample size, the power (1-β) was approximately 0.994.

3.3.2 Results of working memory

The results revealed that the main effect of time on working memory was significant [$F_{(2,100)} = 3.669$, $p = 0.039$, $\eta^2_p = 0.068$], indicating a trend of change in working memory over time. Conversely, no significant difference was observed in the main effect of group on working memory [$F_{(1,50)} = 0.298$, $p = 0.588$, $\eta^2_p = 0.006$], and the time * group interaction was also non-significant [$F_{(2,100)} = 1.181$, $p = 0.304$, $\eta^2_p = 0.023$] (see Table 3).

A subsequent analysis of simple effects was conducted, and the following results are shown in Figure 7.

There were significant differences in working memory at different time points in the experimental group [$F_{(2,49)} = 6.403$, $p = 0.003$, $\eta^2_p = 0.207$]. The working memory of the experimental group at 14 weeks was significantly better than that at the pretest [$t_{(27)} = 3.756$, $p = 0.004$, Cohen's $d = 0.710$], but there was no significant difference between 12 weeks and the pretest [$t_{(27)} = 1.775$, $p = 0.296$, Cohen's $d = 0.336$] and no significant difference between 12 and 14 weeks [$t_{(27)} = 1.473$, $p = 0.469$, Cohen's $d = 0.664$]. The time-course effect of working memory showed that 14 weeks > 12 weeks, pretest. That is, the 14-week exercise intervention combining aerobic exercise and resistance training could improve the working memory of obese junior high school students, with a longer exercise intervention time correlating with better improvement of working memory. Conversely, no significant differences in working memory were observed across the three time points in the control group [$F_{(2,49)} = 0.364$, $p = 0.697$, $\eta^2_p = 0.015$].

A *post hoc* power analysis was conducted using G*Power version 3.1.9.7 (Kang, 2021), with an effect size f of 0.153 (partial η^2 as 0.023), α as 0.05, group as 2, number of measurements as 3, and correlation as 0.619. Within our selected total sample size, the power (1-β) was approximately 0.661.

3.3.3 Results of cognitive flexibility

The results revealed that the main effect of time was significant [$F_{(2,100)} = 12.242$, $p < 0.01$, $\eta^2_p = 0.197$], indicating a trend of change in cognitive flexibility over time. The interaction effect of time * group was also significant [$F_{(2,100)} = 3.913$, $p = 0.023$, $\eta^2_p = 0.073$], indicating a significant difference in the change in cognitive flexibility between the experimental and control groups at different time points. Conversely, the group main effect was not significant [$F_{(1,50)} = 2.164$, $p = 0.148$, $\eta^2_p = 0.041$] (see Table 4).

A subsequent analysis of simple effects was conducted, and the following results are shown in Figure 8.

There were significant differences in cognitive flexibility at different time points in the experimental group [$F_{(2,49)} = 14.160$, $p < 0.01$, $\eta^2_p = 0.366$]. The cognitive flexibility of the experimental group at 12 [$t_{(27)} = 4.217$, $p = 0.001$, Cohen's $d = 0.797$] and 14 weeks were significantly better than the pretest [$t_{(27)} = 4.714$, $p < 0.01$, Cohen's $d = 0.890$], but there was no significant difference between 12 and 14 weeks [$t_{(27)} = 1.900$, $p = 0.416$, Cohen's $d = 0.359$]. The time-course effect of cognitive flexibility showed that 14 and 12 weeks > pretest. That is, the 14-week exercise intervention combining aerobic exercise and resistance training could improve the cognitive flexibility of obese junior high school students, and the effect remained stable with the increase in exercise intervention time. Conversely, no significant differences in cognitive flexibility were observed across the three time points in the control group [$F_{(2,49)} = 0.985$, $p = 0.381$, $\eta^2_p = 0.039$].

There was a significant difference between obese and healthy weight junior high school students in cognitive flexibility at pretest [$F_{(2,100)} = 6.14$, $p = 0.017$, $\eta^2_p = 0.109$], and there was no significant difference in cognitive flexibility at 12 [$F_{(2,100)} = 1.18$, $p = 0.282$, $\eta^2_p = 0.023$] or 14 weeks [$F_{(2,100)} = 0.02$, $p = 0.898$, $\eta^2_p = 0.000$]. That is, before the exercise intervention, the cognitive flexibility of healthy weight junior high school students was better than that of obese peers. After the exercise intervention, the cognitive flexibility of obese junior high school students aligned with that of healthy weight peers across all assessment time points.

A *post hoc* power analysis was conducted using G*Power version 3.1.9.7 (Kang, 2021), with an Effect size *f* of 0.281 (partial η^2 as 0.073), α as 0.05, group as 2, number of measurements as 3, and correlation

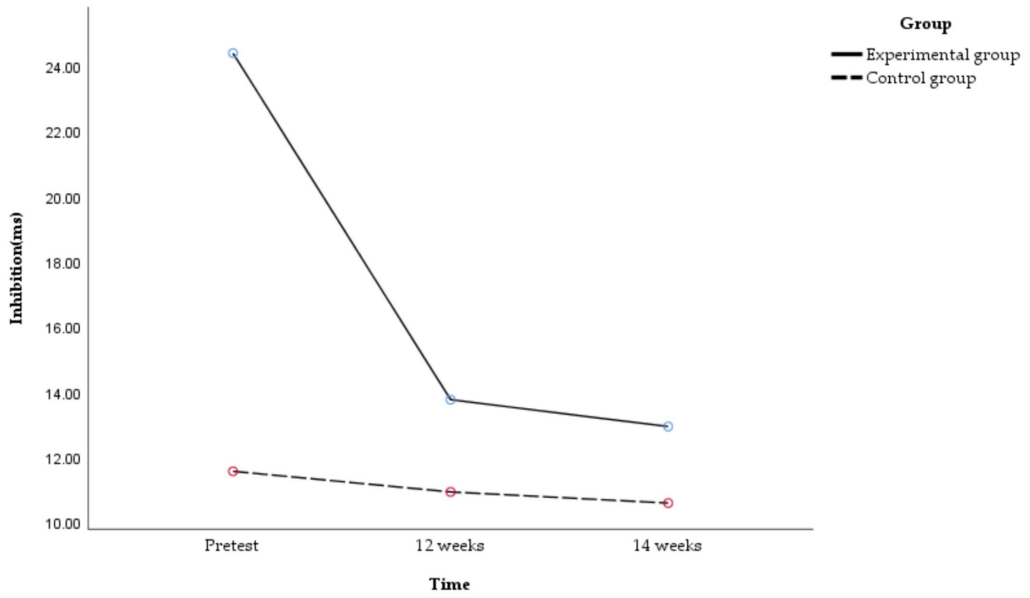

FIGURE 6
Temporal changes in inhibition in obese and healthy weight junior high school students.

TABLE 3 ANOVA results on the effect of exercise intervention on working memory in obese junior high school students.

Interaction effect	Type III sum of squares	df	Mean square	*F*	*p*	η^2_p
Group	17934.972	1	17934.972	0.298	0.588	0.006
Time	128367.279	2	79922.483	3.669	0.039*	0.068
Time * group	41336.161	2	25736.221	1.181	0.304	0.023

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

as 0.581. Within our selected total sample size, the power (1-β) was approximately 0.995.

3.4 Effects of exercise intervention on BMI and BFR of obese junior high school students

3.4.1 Comparison of BMI and BFR between obese junior high school students and healthy weight junior high school students

To investigate the difference of BMI and BFR between obese and healthy weight junior high school students, the Independent-samples *T*-test was conducted for BMI and BFR of the pretests. The results revealed that the BMI [$t_{(50)} = 16.527$, $p < 0.01$, Cohen's $d = 4.606$] and BFR [$t_{(50)} = 13.537$, $p < 0.01$, Cohen's $d = 3.781$] of obese junior high school students were higher than those of healthy peers, and the difference was significant. That is, the BMI and BFR of obese junior high school students were significantly higher than those of healthy weigh peers (see Table 5).

3.4.2 Effects of exercise intervention on BMI of obese junior high school students

The repeated-measures ANOVA was used with the following results to analyze the effects of the exercise intervention on BMI in obese junior high school students.

The results revealed that the main effect of time on BMI was nearly significant [$F_{(1,50)} = 3.998$, $p = 0.051$, $\eta^2_p = 0.074$], indicating a trend of change in BMI over time. The main effect of group on BMI was significant [$F_{(1,50)} = 216.342$, $p < 0.01$, $\eta^2_p = 0.812$], indicating a significant difference in BMI between the experimental and control groups. The interaction effect of time * group was also significant [$F_{(1,50)} = 23.988$, $p < 0.01$, $\eta^2_p = 0.324$], indicating a significant difference in the change in BMI between the experimental and control groups at pretest and 14 weeks (see Table 6).

Further simple effects analysis was performed, and the following results are shown in Figure 9.

The 14 weeks BMI of obese junior high school students in the experimental group was significantly different from the pretest [$t_{(27)} = 4.312$, $p < 0.01$, Cohen's $d = 0.815$], while the 14 weeks BMI of healthy weight junior high school students in the control group was significantly different from the pretest [$t_{(23)} = -2.670$, $p = 0.014$, Cohen's $d = 0.545$]. That is, the 14-week of exercise intervention combining aerobic exercise and resistance training can improve the BMI of obese junior high school students, while the BMI of healthy weight junior high school students has an upward trend.

There was a significant difference between the experimental group and the control group in BMI at pretest [$F_{(1,50)} = 273.13$, $p < 0.01$, $\eta^2_p = 0.845$], and there was also a significant difference in BMI at 14 weeks [$F_{(1,50)} = 126.14$, $p < 0.01$, $\eta^2_p = 0.716$]. That is, before exercise intervention, the BMI of healthy weight junior high school students in the control

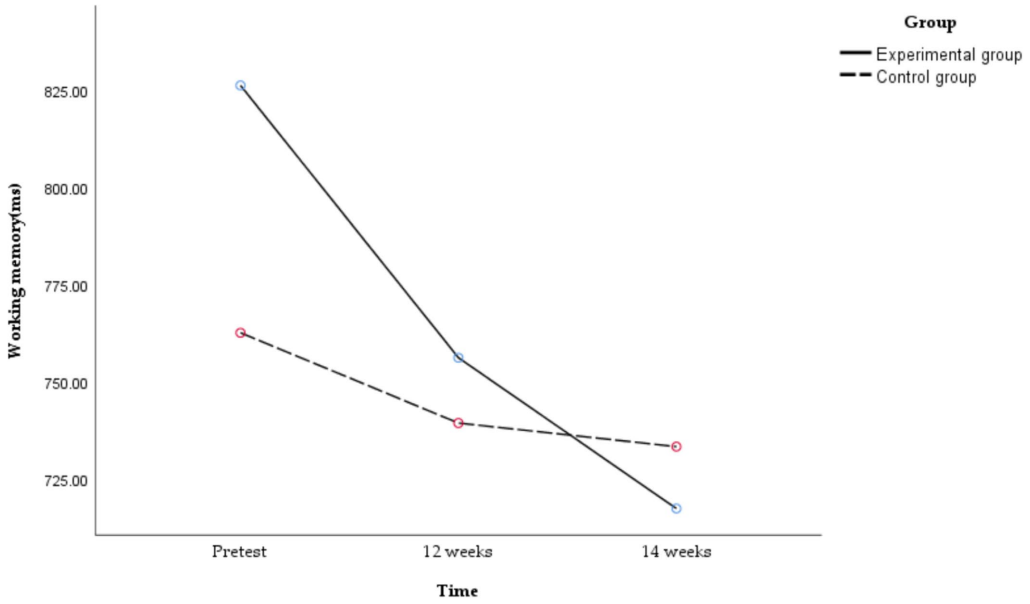

FIGURE 7
Temporal changes in working memory in obese and healthy weight junior high school students.

TABLE 4 ANOVA results on the effect of exercise intervention on cognitive flexibility in obese junior high school students.

Interaction effect	Type III sum of squares	df	Mean square	*F*	*p*	η^2_p
Group	101169.019	1	101169.019	2.164	0.148	0.041
Time	209111.331	2	104555.666	12.242	<0.01**	0.197
Time * group	66835.015	2	33417.507	3.913	0.023*	0.073

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

group was better than that of obese junior high school students in the experimental group. After exercise intervention, the BMI of healthy weight junior high school students in the control group was still better than that of obese junior high school students in the experimental group.

3.4.3 Effects of exercise intervention on BFR of obese junior high school students

The repeated-measures ANOVA was used with the following results to analyze the effects of the exercise intervention on BFR in obese junior high school students.

The results revealed that the main effect of time on BFR was significant [$F_{(1,50)} = 17.617$, $p = 0.046$, $\eta^2_p = 0.077$], indicating a trend of change in BFR over time. The main effect of group on BFR was significant [$F_{(1,50)} = 138.144$, $p < 0.01$, $\eta^2_p = 0.734$], indicating a significant difference in BFR between the experimental and control groups. The interaction effect of time * group was also significant [$F_{(1,50)} = 438.140$, $p < 0.01$, $\eta^2_p = 0.675$], indicating a significant difference in BFR between the experimental and control groups at pretest and 14 weeks (see Table 7).

Further simple effects analysis was performed, and the following results are shown in Figure 10.

The 14 weeks BFR of obese junior high school students in the experimental group was significantly different from the pretest [$t_{(27)} = 8.910$, $p < 0.01$, Cohen's $d = 1.685$], while the 14 weeks BFR of healthy weight junior high school students in the control group was significantly different from the pretest [$t_{(23)} = -5.625$, $p < 0.01$, Cohen's $d = 1.146$]. That is, the 14-week exercise intervention combining aerobic exercise and resistance training can improve the BFR of obese junior high school students, while the BFR of healthy weight junior high school students has an upward trend.

There was a significant difference between the experimental group and the control group in BFR at pretest [$F_{(1,50)} = 183.257$, $p < 0.01$, $\eta^2_p = 0.786$], and there was also a significant difference in BFR at 14 weeks [$F_{(1,50)} = 82.72$, $p < 0.01$, $\eta^2_p = 0.623$]. That is, before exercise intervention, the BFR of healthy weight junior high school students in the control group was better than that of obese junior high school students in the experimental group. After exercise intervention, the BFR of healthy weight junior high school students in the control group was still better than that of obese junior high school students in the experimental group.

4 Discussion

4.1 Analysis of the developmental characteristics of EF in obese junior high school students

This study supported the hypothesis that obese adolescents exhibit impaired EF compared to their healthy weight peers, particularly in inhibition and cognitive flexibility. These findings aligned with

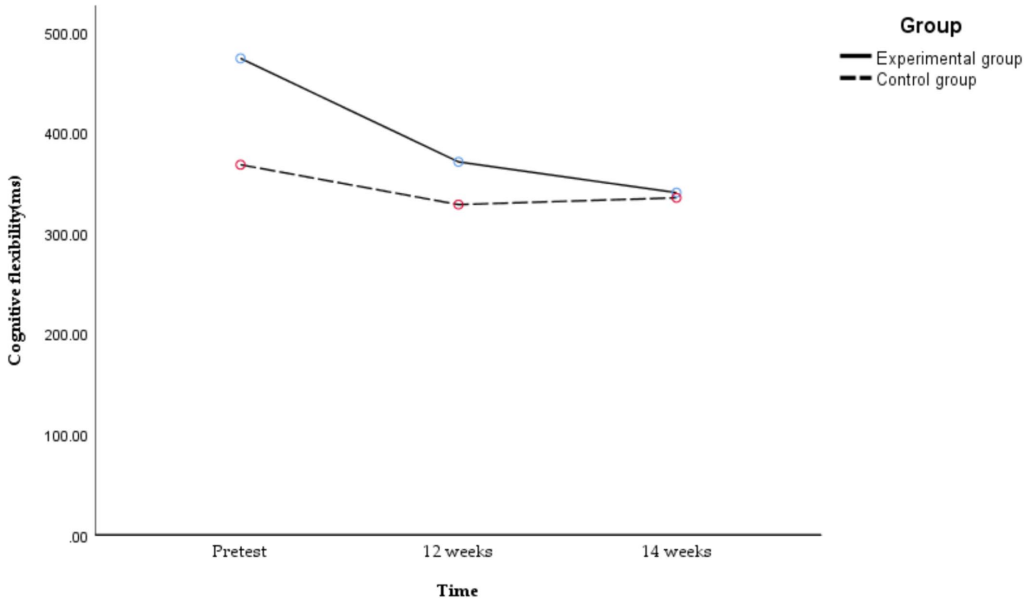

FIGURE 8
Temporal changes in cognitive flexibility in obese and healthy weight junior high school students.

TABLE 5 Results of the independent-samples *T*-test of BMI and BFR in obese and healthy weight junior high school students (M ± SD).

Index	Obese junior high school students	Healthy weight junior high school students	*t*	*p*	Cohen's *d*
BMI	28.75 ± 2.42	17.85 ± 2.30	16.527	<0.01**	4.606
BFR	39.50 ± 6.22	17.07 ± 5.63	13.537	<0.01**	3.781

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

previous research demonstrating similar findings in obese adolescents. Gentier et al. (2013) found EF impairment and motor perception dysfunction in obese children compared to healthy weight children, and Martí-Nicolovius (2022) found deficits in cognitive function in obese children and adolescents, further highlighting the pervasive impact of obesity on cognitive abilities.

The physiological mechanisms behind the poor development of EF in obese junior high school students may be that obese people have a high fat content, which leads to a significant reduction in cerebral blood flow and speed, insufficient blood supply to the brain, and a decrease in blood oxygen saturation, which affects their brain metabolic processes (Ebbeling et al., 2002; Guo and Chen, 2015). In terms of brain mechanisms, obese people have reduced volume and functional connectivity in brain areas related to EF (Willette and Kapogiannis, 2015), resulting in damage to the wiring system connecting the information processing areas of the brain, which in turn hinders the transmission of signals, leading to slow thinking and slow response, which negatively affects the development of EF.

The implications of our findings were profound, indicating that the compromised EF in obese adolescents could have broader consequences for their overall health and well-being. Given the pivotal role of EF in academic achievement and social adaptation, addressing this issue was not only crucial for the students' immediate cognitive development but also for their long-term success and mental health. This study thus called for the development and implementation of targeted interventions aimed at enhancing EF in obese adolescents.

4.2 Time-course effects of exercise intervention combining aerobic exercise with resistance training on EF in obese junior high school students

This study supported the hypothesis that exercise intervention combining aerobic exercise with resistance training can significantly enhances EF in obese adolescents. These findings aligned with previous research indicating the cognitive benefits of both aerobic and resistance training for obese adolescents (Guo et al., 2016). However, this study stood out by adopting an innovative approach that combines these two exercise modalities, focusing on three key pathways—action characteristics, exercise intensity, and exercise scenarios—to optimize EF improvement. The selection of complex, novel, and targeted actions, adjusted dynamically to the external environment, along with moderate-intensity exercise and diverse scenarios, constituted the unique aspect of our intervention. This multifaceted approach effectively improved EF in obese adolescents.

Beyond the three key pathways, the physiological mechanisms underlying our exercise intervention' s efficacy in improving EF warrant attention. Long-term aerobic exercise combined with resistance training intervention successfully reduced fat content, enhanced blood circulation, and improved blood oxygen saturation

TABLE 6 ANOVA results on the effect of exercise intervention on BMI in obese junior high school students.

Interaction effect	Type III sum of squares	df	Mean square	*F*	*p*	η^2_p
Group	2399.886	1	2399.886	216.342	<0.01**	0.812
Time	6.844	1	6.844	3.998	0.051	0.074
Time * group	41.060	1	41.060	23.988	<0.01**	0.324

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

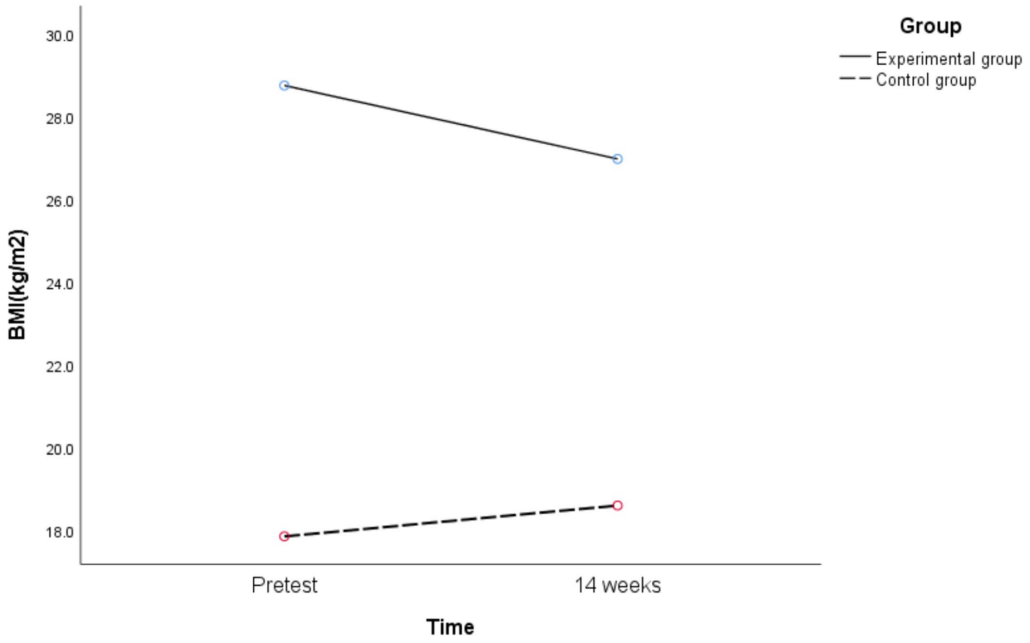

FIGURE 9
Changes of BMI in different groups before and after exercise intervention.

TABLE 7 ANOVA results on the effect of exercise intervention on BFR in obese junior high school students.

Interaction effect	Type III sum of squares	df	Mean square	*F*	*p*	η^2_p
Group	8667.447	1	8667.447	138.144	<0.01**	0.734
Time	17.617	1	17.617	4.178	0.046*	0.077
Time * group	438.140	1	438.140	103.912	<0.01**	0.675

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

in obese junior high school students. These physiological changes activated brain regions and functional connectivity associated with EF, as well as enhanced hippocampal insulin signaling and neuroplasticity (Chen et al., 2011a,b; Guo et al., 2016; Park et al., 2019). These findings contributed to the understanding of how combined exercise interventions can specifically target and improve EF in obese adolescents.

Utilizing a multi-time-point measurement design, our study uniquely explored the time-course effects of the exercise intervention on the three sub-functions of EF: inhibition, working memory, and cognitive flexibility. Our results indicated that different intervention cycles had selective positive effects on these sub-functions. Notably, inhibition and cognitive flexibility significantly improved at 12 weeks, while working memory significantly improved at 14 weeks. These findings build upon Yin et al.'s (2014) study, suggested that longer intervention durations may yield better EF outcomes. This study underscored the importance of identifying optimal time points for significant EF changes.

Throughout the exercise intervention, participants engaged in continuous inhibition of dominant responses and conscious muscle control during resistance training, which likely contributed to the significant improvements in inhibition. Cognitive flexibility was enhanced through the need for constant movement transitions in response to changing exercise commands and rules. Working memory

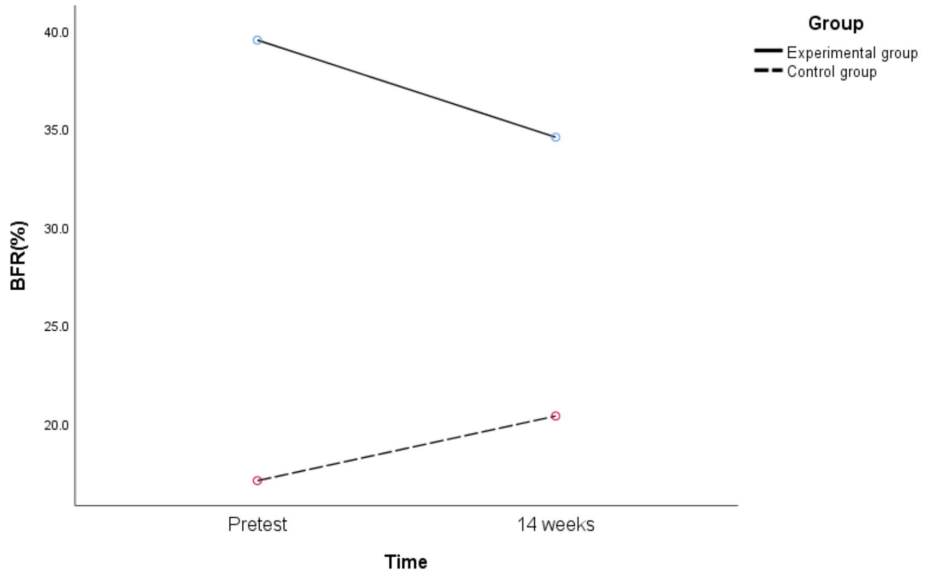

FIGURE 10
Changes of BFR in different groups before and after exercise intervention.

improvement was attributed to the participants' requirement to memorize movements and game rules, and responded quickly in dynamic situations. Our focus on improving inhibition and cognitive flexibility, areas typically weaker in obese students compared to their healthy weight peers, may explained the earlier observed changes in these sub-functions. This targeted approach to exercise intervention design represents a novel strategy for optimizing EF development in obese adolescents.

4.3 The strengths and the limitations of this study

This study's novel contribution lied in the specific focus on the time-course effects of the exercise intervention. This provided valuable insights into the optimal timing and duration of exercise interventions for EF development in obese adolescents. Additionally, the combination of aerobic exercise and resistance training, along with the multifaceted approach incorporating action complexity and diverse exercise scenarios, offered a unique perspective on the potential mechanisms underlying the observed improvements. In addition, the health implications of this study were significant. Improved EF can enhance academic performance, social interactions, and overall cognitive functioning, ultimately improving the quality of life for obese adolescents. This study provided evidence supporting the potential of exercise as a non-pharmacological intervention for improving cognitive function and overall health in obese adolescents.

Despite its strengths, this study had limitations. The relatively shorted duration of the intervention and limited number of time points for EF measurements warrant further research exploring the long-term effects of exercise on the development of EF in obese adolescents as well as the late effects. Additionally, increasing the sample size and incorporating brain imaging techniques could provide valuable insights into the neural mechanisms underlying the observed improvements. Future research could also explored the impact of exercise on other cognitive functions, such as attention and memory, in obese adolescents. Additionally, investigating the effectiveness of targeted exercise interventions for different sports could provide valuable insights into the optimal exercise prescription for improving EF in obese adolescents.

5 Conclusion

Obese adolescents had impaired EF, as evidenced by low levels of the inhibition and cognitive flexibility compared to healthy weight adolescents. The exercise intervention combining aerobic exercise and resistance training had a positive effect on EF of obese adolescents. The time-course effects of the intervention on improvements in inhibition, working memory, and cognitive flexibility varied with intervention duration in obese adolescents, with significant changes in inhibition and cognitive flexibility observed at 12 weeks and significant changes in working memory at 14 weeks.

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 institutional review board of the National Key Laboratory of

Cognitive Neuroscience and Learning. 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

LH: Writing – original draft. QS: Writing – original draft. HY: Writing – original draft. LC: Writing – original draft.

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Conflict of interest

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

Publisher's note

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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Giuseppe Mannino,
Libera Università Maria SS. Assunta, Italy
Miguel Pic,
University of La Laguna, Spain

*CORRESPONDENCE
Filipe Rodrigues
✉ filipe.rodrigues@ipleiria.pt

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Social support, network, and relationships among coaches in different sports: a systematic review

João Gonçalo Ferreira[1,2], Filipe Rodrigues[3,4,*], Pedro Sobreiro[1,2], Mário Silva[2,5], Fernando Jorge Santos[2,6,7], Gonçalo Carvalho[1,2], António Hernández Mendo[8] and José Rodrigues[1,2]

[1]Sport Sciences School of Rio Maior, Polytechnic University of Santarém, Rio Maior, Portugal, [2]Life Quality Research Centre, Santarém, Portugal, [3]ESECS – Polytechnic of Leiria, Leiria, Portugal, [4]Research Center in Sports, Health, and Human Development, Vila Real, Portugal, [5]School of Health Sciences, Polytechnic University of Santarém, Rio Maior, Portugal, [6]School of Education, Polytechnic University of Setúbal, Setúbal, Portugal, [7]Faculty of Human Kinetics, University of Lisbon, Cruz Quebrada, Portugal, [8]Department of Social Psychology, Social Anthropology, Social Work and Social Services, University of Malaga, Málaga, Spain

Introduction: The study aims to analyze scientific publications on the association between social networks, social relationships, and social support for sports coaches. It seeks to identify the types and levels of social support provided by various agents, and to understand the impact of this support on coaches' wellbeing. The goal is to help coaches better utilize social support, thereby enhancing their quality of life, work, and performance.

Methods: This study systematically reviewed 11 scientific articles to investigate the association between social support, social networks, and social relationships in sports coaches. It aimed to identify the types and levels of social support offered to coaches by family members, peers, and friends. Our research utilized the PRISMA guidelines for systematic reviews and assessed study quality using the STROBE Statement. Eligibility was determined by the PECOS criterion based on the search strategy terms.

Results: Our findings indicate that social support has significant positive effects on sports coaches. It enhances selfcompassion, prevents burnout symptoms, boosts job and life satisfaction, and reduces stress levels. Organizational support, characterized by clear guidelines, guidance, and autonomy, yielded positive outcomes. Conversely, the absence of social support correlated with negative outcomes for coaches, including lower self-compassion, increased stress and burnout symptoms, reduced job and life satisfaction, and heightened work–family conflict. Coaches' social networks encompassed family members, peers, friends, and other sources, with friends perceived as the most influential. Maintaining an effective social support network is crucial for coaches' performance and psychological wellbeing.

Discussion: This systematic review emphasizes the importance of social support for coaches in both their personal and professional lives, noting its positive effects and the negative consequences of its absence. Given the demanding nature of coaching, improving social support systems can enhance coaches' wellbeing and the success of sports activities.

KEYWORDS

social support, social network, social relationships, sport, coaching

1 Introduction

The role of a sports coach is pivotal in enhancing various facets of the athletes, including physical, technical, mental, and tactical aspects, while concurrently playing a crucial role in their personal and social development (Fletcher and Scott, 2010). Given the competitive, intricate, and ever-evolving environment within which sports coaches operate, coupled with the multifaceted responsibilities assigned to them, there has been a burgeoning interest in assessing social support within sports training (Knights and Ruddock-Hudson, 2016; Mannino et al., 2019).

Sports coaching is widely recognized as a demanding profession, characterized by stressors such as long and irregular working hours, job insecurity tied to athletic performance, work–family conflicts, and a significant emotional investment in the coaching role. The accumulation of stress can lead some coaches to experience negative mental health outcomes like burnout, potentially prompting them to leave their positions. However, the impact on mental health varies among coaches, influenced in part by both risk and protective factors. Previous research has predominantly focused on stressors rather than protective factors. Noteworthy protective elements encompass grit, psychosocial resilience, coping skills, self-compassion, and social support. Recent research has shown increasing interest in the latter two factors, as they are believed to enhance overall wellbeing and coping mechanisms in coaches (Ackeret et al., 2022).

The documented benefits of social support in various professions stand in stark contrast to the relatively limited research related to social support among sports coaches (Norris et al., 2020). The existing literature characterizes "social support" as encompassing "comfort, care, assistance, and information that a person receives from others." In the sports context, social support has been employed to describe the overall quality of relationships, perceived support, availability, or received support, or the size of an individual's social network (Rees and Hardy, 2000; Bruner et al., 2021). Hobfoll et al. (1990) have underscored the pivotal role of social support and connections within a social network in shielding recipients and preserving their sense of identity.

Like resilient coping, social support is recognized as a protective factor against the adverse effects of negative life experiences. It plays a role in reducing men's resilient coping for psychological distress by influencing the appraisal of stressful events, fostering a sense of understanding, enhancing control or mastery, and promoting the adoption of adaptive coping strategies. Conversely, a lack of social support can diminish resilience to psychological distress, leading to increased isolation, distancing from social connections, and ineffective self-management (Sharp et al., 2023).

According to Sheikh et al. (2016), social support has an influence on an individual's wellbeing. Mannino and Caronia (2017) state that wellbeing, often equated with "being well" or "existing well," encompasses all aspects of human life and defines the quality of life for each individual. It is the result of achieving harmony between people and their environment through adaptation to various lifestyle factors. While it's often likened to happiness, wellbeing has a broader meaning. It involves an ongoing interaction and mutual influence between individual and collective wellbeing, ultimately leading to individual happiness within the social context.

Social support is a multifaceted concept encompassing emotional, informational, esteem, and tangible dimensions. Emotional support involves providing comfort and security during high-stress times, fostering feelings of love and protection. Informational support includes offering guidance or advice to resolve specific issues, addressing concerns like low confidence or fitness. Esteem support reinforces a person's competence and self-esteem, aiding in coping with pressure, such as in sports competitions. Tangible support involves concrete instrumental assistance during stressful situations, such as financial support or help with tasks (Rees and Hardy, 2000; Maciel et al., 2021).

On the player's side, several studies suggest that promoting various forms of social support within the sports context can bolster athletes' motivation (DeFreese and Smith, 2013), self-confidence (Cowan et al., 2012), perceptions of team cohesion (Westre and Weiss, 1991), and performance (Rees et al., 1999). DeFreese and Smith (2013) and other scholars have proposed that received support can serve to reduce athlete burnout, alleviate perceived stress (Rees and Freeman, 2007), and expedite the recovery process from injuries (Abgarov et al., 2012; Clement and Shannon, 2011; Lu and Hsu, 2013).

Although coaching is acknowledged as a notably stressful, intricate, and challenging profession, the academic focus on social support for coaches has not matched that given to athletes. Coaches at various performance levels are tasked with creating effective training programs, recruiting athletes, handling performance-related stress (e.g., competition outcomes) and managing relationships with diverse stakeholders (e.g., athletes, administrators, officials, media, and parents) on a daily basis. It is evident that social support can serve as a valuable resource for coaches, especially when dealing with stressors, as these stressors can have notable consequences on the psychological wellbeing of coaches (e.g., depression) and performance outcomes (e.g., diminished concentration leading to less effective observations) (Norris et al., 2020).

Social support is frequently characterized by considering both the configuration of an individual's network (such as the presence of family ties) and the explicit resources that can be offered by interpersonal relationships (Norris et al., 2020). According to Thoits (1995), the structure of social networks encompasses the number of relationships an individual maintains within their network, the frequency of contact with network members, and the density of relationships they maintain within the network.

An individual's social network comprises primarily family, friends, and peers (Norris et al., 2020). The structure of an individual's social network, such as the presence of familial bonds, and the potential resources offered by interpersonal relationships are concepts intimately intertwined with the concept of social support (Cohen and Wills, 1985). Wellard (2013) research underscores the significance of social relationships in shaping the sporting experiences of participants, influencing their capacity to derive enjoyment from sports engagement. Social relationships also exert a substantial impact on health, lifestyle (Eime et al., 2013; Marques et al., 2016), as well as fostering feelings of belonging and integration (Burrmann et al., 2017; Doidge et al., 2020; Flensner et al., 2021).

Athletes often express that meeting people and socializing with friends serve as compelling motivations for their participation in sports. Most individuals harbors high expectations regarding the social outcomes of their involvement in sports (Bergesen Dalen and Seippel, 2019). Social relationships have a robust association with physical health (House et al., 1988).

Norris et al. (2017), on a systematic review focusing on stressors, coping mechanisms, and wellbeing among coaches, social support emerged in more than 50% of the 38 studies included in the final sample.

The results of this review indicate that coaches commonly rely on social support, and in instances where such support is lacking, coaches tend to report heightened perceptions of stress and diminished performance.

In a meta-analysis, Holt-Lunstad et al. (2010) unearthed a connection between social support and reduced mortality risk, even when accounting for conventional risk factors like age, obesity, and health status. Furthermore, studies by De Vogli et al. (2007) and Friedman et al. (1995) provide evidence that negative social connections are linked to higher mortality rates.

The belief prevails that relationships among individuals are intertwined with sleep quality. Throughout the evolutionary history of our species, sleeping humans have benefited from a secure context, protected from predators and adversaries by those in proximity (Dahl and El-Sheikh, 2007). Studies conducted by Nordin et al. (2008), Rambod et al. (2012), and Troxel et al. (2010) have substantiated the notion that perceived support from others correlates with improvements in both objective and subjective sleep quality. Troxel et al. (2010) study further revealed that individuals perceiving greater social support experienced fewer wakeful periods after falling asleep. Moreover, negativity and interpersonal tension have been associated with sleep quality. A study conducted by Brummett et al. (2006) found that negative emotions linked to caregiving predicted poorer sleep quality, affecting facets such as sleep duration, latency, disturbances, and daytime functionality.

Holt-Lunstad et al. (2010) have provided evidence suggesting that the quantity and quality of social relationships in industrialized societies are on the decline. McPherson et al. (2006) argued that in the United States, the number of people with whom individuals engage in significant conversations has markedly dwindled in recent years, leading to heightened social isolation.

The primary objective of this study is to conduct a comprehensive analysis of scientific publications concerning the interplay between social networks, social relationships, and social support in the context of sports coaches. The aim is to identify the types and levels of social support provided to sports coaches by family members, peers, and friends, understanding the impact that social support will have on various aspects of the coaches' lives, such as wellbeing. In this way, we intend for coaches to have a greater capacity to explore and benefit from social support, improving their quality of life/work and, consequently, their performance.

2 Methods

2.1 Research

For this systematic review, the criteria recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement were followed, which provide guidance for conducting systematic reviews (Moher et al., 2010, 2015). The research protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO - CRD42023423875), available at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42023423875.

2.2 Strategy

The literature search was conducted in the following databases: Web of Science - Core Collection; and B-On (Academic Search Complete, Business Source Complete, Complementary Index, eBook Index, ERIC, MEDLINE, OpenDissertations, Supplemental Index, and Teacher Reference Center). In the search engines of each platform, the following terms related to the study's topic ("Social Support" OR "Social Network" OR "Social Relationships" OR "Peer Support" OR "Family Support") were entered and combined with terms related to the population ("Coach" OR "Instructor" OR "Monitor") and the research context "Sport." Using the Boolean operator "AND" the terms were combined as follows: ("Social Support" OR "Social Network" OR "Social Relationships" OR "Peer Support" OR "Family Support" AND "Coach" OR "Instructor" OR "Monitor" AND "Sport").

2.3 Eligibility criteria

The eligibility criteria for the consulted articles followed the recommendations from the literature for such studies (Meline, 2006). For the analysis, all studies in Portuguese, Spanish, and English published between the years 2000 and 2023 (21st century) were considered. Initially, eligibility assessment was conducted by two researchers in the field of sports coaching, in a standardized and independent manner. Subsequently, the assessment by the two researchers was shared with a group of six researchers who performed a new evaluation to ensure consensus among all. The inclusion and exclusion of studies were done using the PECOS criteria (Table 1). In the PECOS criteria, researchers began by excluding studies that involved athletes as participants and included studies that involved coaches and their family, peers, and friends. In the exposure, studies that integrated sports coaching and competition were included, while those related to school physical education were excluded. In the comparison, studies with social agents such as coaches, family, peers, and friends were included. Regarding results, studies that encompassed social support, social networks, social relationships (for/from coaches) (interaction, influence, and association) were included, and consequently, studies addressing the perception of athletes were excluded. Finally, regarding the study itself, those that conducted empirical and instrumental research, both qualitative and quantitative (field studies – descriptive, cross-sectional, and longitudinal), were included, while experimental and theoretical studies were excluded. Figure 1 shows the procedures carried out from the identification stage to the selection of final studies. After searching the selected databases, on February 10, 2023, 231 studies were identified. In the identification phase, filtering was applied to the databases (78 studies excluded due to publication date and document type), and duplicate studies were removed (73 studies excluded). In the screening phase, titles (50 excluded) and abstracts (19 excluded) were read. In the eligibility phase, the remaining studies were read (0 excluded), resulting in 11 studies included in the final stage. Figure 1 depicts the flowchart of the article selection process carried out in this systematic review.

2.4 Assessment of methodological quality of studies

The methodological quality of each study under analysis was independently assessed by two researchers using the STROBE Checklist (Von Elm et al., 2007). All items from the STROBE Checklist were used, except item 6(b), due to the absence of paired studies. The studies were classified based on the following cut-off points: A (>80%

TABLE 1 Inclusion and exclusion criteria for selected studies in the review.

		Inclusion	Exclusion
P	Participant	Coaches (family, peers, and friends)	Athletes
E	Exposure	Sports training and competition	School physical education
C	Comparison	Social agents: family, peers, and friends support type: informational, emotional, tangible, and esteem Support Level: positive, indifferent, and negative	--
O	Outcome	Social support; social network; social relationships (to coaches) (interaction; influence; association)	Athletes' perception
S	Study	Empirical and Instrumental Investigation (field studies - descriptive, cross sectional and longitudinal)	Experimental and theoretical

high); B (50–80% moderate); and C (<50% low). The cut-off points were derived from the sum of the scores assigned to each item: 0 (does not address); 1 (addresses) (Olmos et al., 2008). Disagreements between researchers were resolved through consensus. Table 2 presents the results of the methodological quality for the studies included.

2.5 Risk of bias

Based on the guidelines used (Von Elm et al., 2007; Olmos et al., 2008), one study was classified as high methodological quality, six studies were classified as moderate quality, and four studies were classified as low quality. Overall, the risk of bias in the studies was rated as moderate.

2.6 Data extraction and analysis

The extracted studies were organized using Zotero software. Based on the information presented in each study, characteristics (publication year, sample type, type of sport, investigated social agents, research type, and instruments) were analyzed.

2.7 Study characteristics

The characteristics of the 11 studies selected for this systematic review are presented in Table 2. Of the total number of studies, 8 were published from the year 2015 onward. Regarding the study location, 1 study was conducted in Switzerland, 1 study in New Zealand, 1 study in Spain, 1 study in South Korea, 1 study in Singapore, 2 studies in South Africa, 2 studies in Australia, and 2 studies in the United Kingdom. Most of the studies ($n = 8$) were conducted with participants of both sexes, while 2 studies were conducted only with male participants and 1 study with female participants. Regarding the type of sports, 7 studies included both individual and team sports, 3 studies included only team sports, and 1 study did not specify the types of sports included in the sample. Regarding the instruments used, 5 studies used questionnaires, and 6 studies used semi-structured interviews, with 1 of those studies also using sociograms provided by the interviewee.

3 Results and discussion

The primary objective of this systematic review was to explore and analyze the existing literature on social support, social network, and social relationships of coaches across various sports disciplines. To achieve this, we conducted a comprehensive analysis of studies published between 2000 and 2023, focusing on the types of social support received by coaches, the impact of social networks on their wellbeing, and the dynamics of their social relationships with family, peers, and friends.

In our analysis of the 11 identified studies, we qualitatively assessed the results related to three main themes: social support, social networks, and social relationships. This included examining several types of social support coaches receive (from family, peers, and friends), such as emotional, informational, esteem, and tangible support, as well as the various levels of support (positive, neutral, and negative) perceived by coaches (Figures 2–4).

In the studies analyzed, the social support provided by the family was mainly emotional (3 studies), demonstrating positive effects on the coach's wellbeing. Tangible support (2 studies) was also positively received by coaches, in situations where they had little time to carry out tasks and resorted to help from family members.

Social support provided by peers was mainly informational (3 studies) and tangible (3 studies), both with positive effects on sports coaches. Informational support was mostly used by coaches to discuss about training sessions with other coaches, while tangible support was based on help from assistant coaches in carrying out tasks.

Friends also had a positive impact on coaches' wellbeing, providing both informational (1 study) and emotional (1 study) support. Usually, coaches spend time with their friends to "get away" from their working routine, looking to take their mind off work for a while.

Within the scope of the studies reviewed, social support emerged as a crucial factor with positive effects on sports coaches across multiple dimensions (Figure 5). Notably, social support was associated with increased self-compassion (Ackeret et al., 2022), the prevention of burnout symptoms (Ackeret et al., 2022; Ha et al., 2021), heightened job and life satisfaction (Kubayi, 2018), and reduced stress levels (Norris et al., 2022; Knights and Ruddock-Hudson, 2016). Additionally, regarding the family, organizational support, was found to have positive effects by reducing work–family conflicts (Kubayi, 2018).

The support provided to coaches by the respective organizations demonstrated positive effects (e.g., coaches felt support for their psychological needs) when there were clear guidelines and guidance, as well as the possibility for coaches to work in contexts of high autonomy. On the other hand, organizations lacking such directives did not reveal such positive results. The extent to which the environment was perceived as autonomy supportive seemed to be significantly influenced by the relationships among coaches and key personnel within sports organizations (Allen and Shaw, 2009).

Findings from studies by Norris et al. (2020), Norris et al. (2022), underscored the importance of all four types of social support (emotional, informational, esteem, and tangible) in yielding positive effects, including stress reduction and improved wellbeing, for

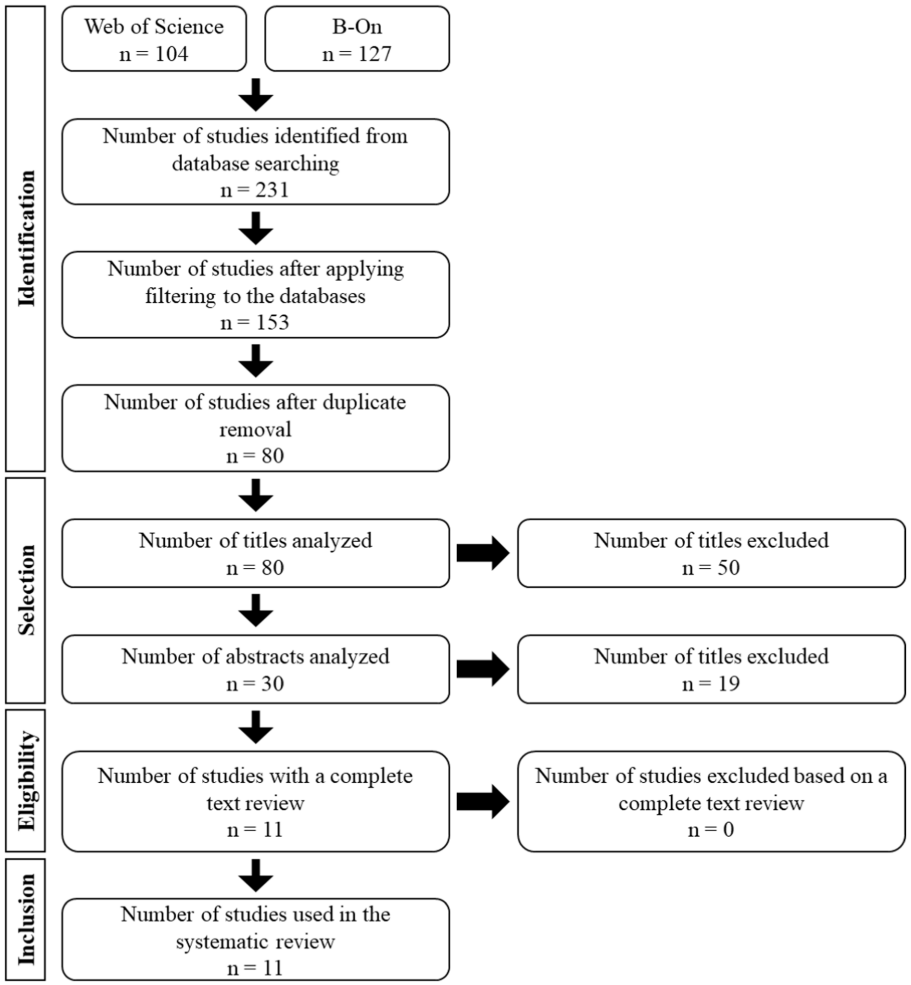

FIGURE 1
PRISMA flowchart.

TABLE 2 Study characteristics.

Authors and year	Location	Sex	Modality	Instruments	Study quality
Ackeret et al. (2022)	Switzerland	M + F	Individual + Team	Questionnaire	A
Allen and Shaw (2009)	New Zealand	F	Individual + Team	Semi-structured Interview	C
del Prado et al. (2012)	Spain	M + F	Individual + Team	Questionnaire	C
Ha et al. (2021)	South Korea	M + F	Individual + Team	Questionnaire	B
Knights and Ruddock-Hudson (2016)	Australia	M	Team	Semi-structured Interview	C
Teck Koh et al. (2019)	Singapore	M + F	Individual + Team	Semi-structured Interview	B
Kubayi (2018)	South Africa	M + F	Team	Questionnaire	B
Norris et al. (2020)	United Kingdom	M + F	Individual + Team	Semi-structured Interview and Sociograms Assisted by Interviewee	B
Norris et al. (2022)	United Kingdom	M + F	Individual + Team	Semi-structured Interview	B
Occhino et al. (2013)	Australia	M	Team	Semi-structured Interview	C
Pelser-Carstens et al. (2015)	South Africa	M + F	N/A	Questionnaires	B

M, male; F, female; A, high; B, moderate; C, low.

coaches. Conversely, the absence of social support tended to result in various negative outcomes in coaches' lives, such as decreased self-compassion, increased stress and burnout symptoms, job and life dissatisfaction, and heightened work–family conflicts (Ackeret et al., 2022; Ha et al., 2021; Knights and Ruddock-Hudson, 2016; Kubayi, 2018; Norris et al., 2022).

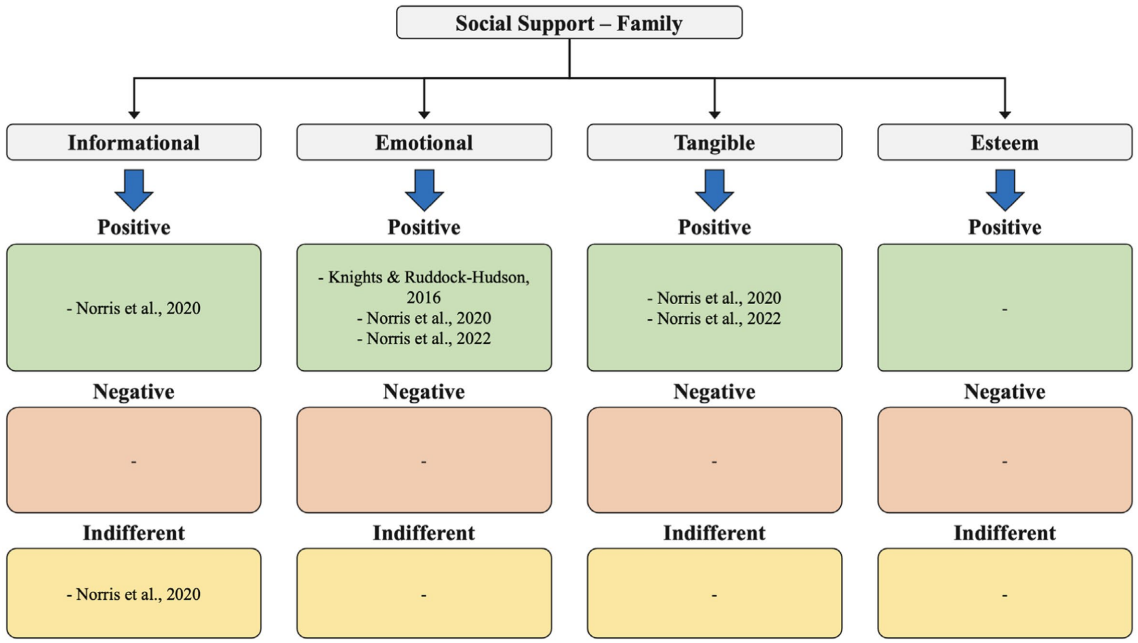

FIGURE 2
Social support – family.

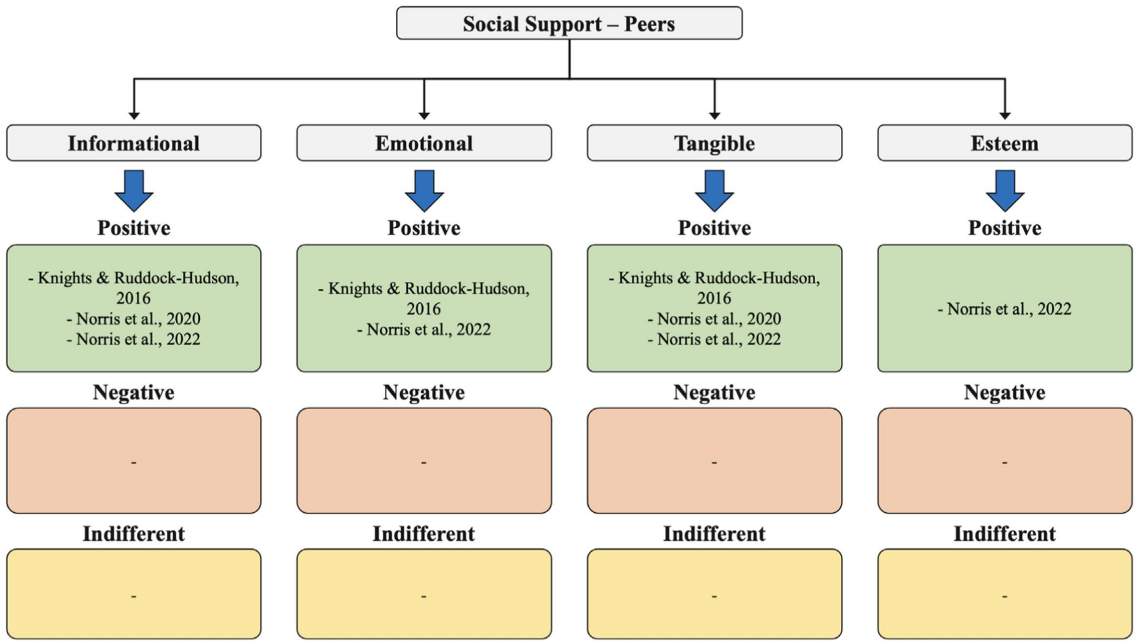

FIGURE 3
Social support – peers.

In terms of social networks, studies by Norris et al. (2020) illuminated the comprehensive nature of coaches' social networks, encompassing colleagues, friends, family members, and other entities (e.g., media). Ego-network diagrams from the study revealed coaches' tendencies to seek more support from peers, but they often perceived support from friends as the most influential. These diagrams have been created to illustrate the social support utilized by coaches and the proximity of that support. They were formulated based on the sociograms generated from coaches' interviews. In addition to the ego-network diagrams, insights from interviewees are incorporated through relevant quotes. The results underscored the potential positive impact of maintaining an effective social support network on coaches' performance and psychological wellbeing.

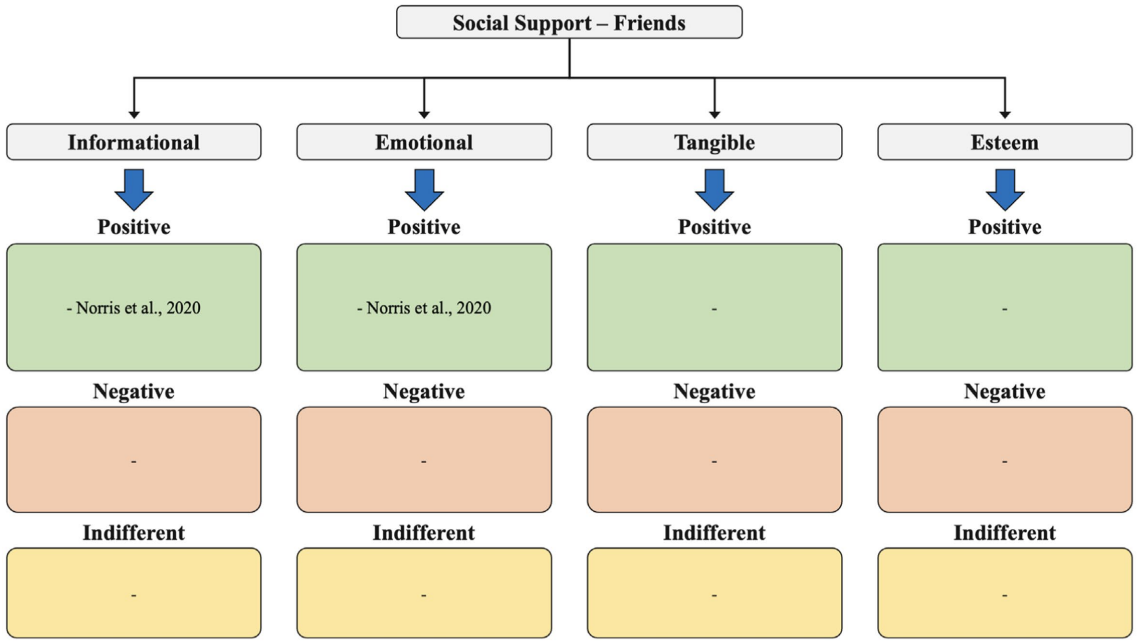

FIGURE 4
Social support – friends.

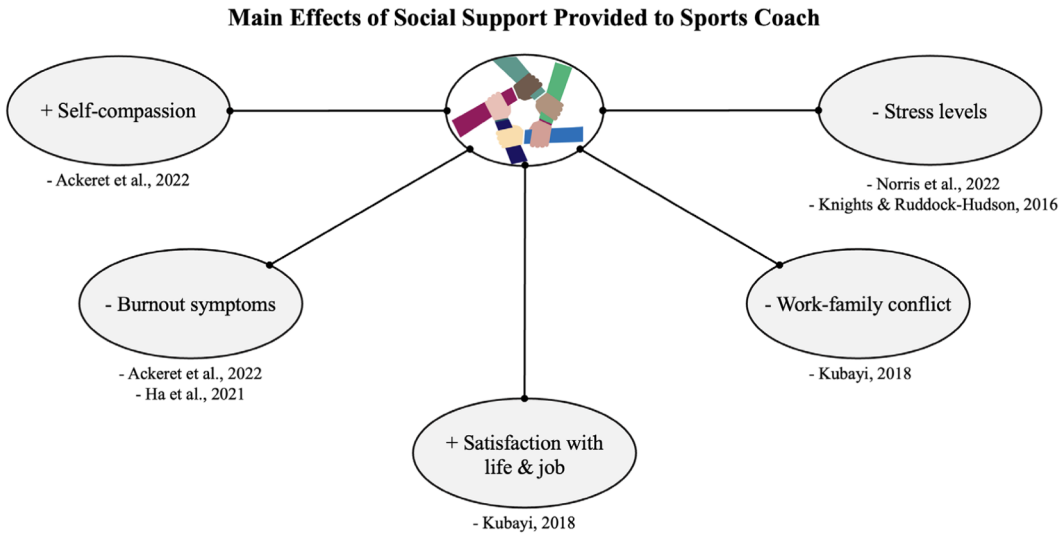

FIGURE 5
Main effects of social support provided to sports coach.

This systematic review highlighted the significance of social support, social networks, and social relationships in the lives of sports coaches. The findings emphasize the positive effects of social support and the importance of clear guidelines and autonomy within organizations. However, there is a notable gap in scientific literature on this topic, calling for further research to explore and develop a comprehensive conceptual framework integrating social variables and blending quantitative and qualitative methodologies. The study underscores the need for coaches and sports organizations to prioritize social support, considering the competitive and challenging environments coaches navigate, which can otherwise lead to negative consequences for coaches' wellbeing.

4 Conclusion

The results of this systematic review provide valuable insights into the diverse types and levels of social support provided to coaches by individuals in their social networks. It was found that coaches' social networks encompass colleagues, friends, family, and others.

The social support received by coaches was crucial in promoting various positive effects, such as reducing stress, preventing burnout symptoms, increasing job and life satisfaction, and improving work-family relationships. The social support provided by coaches to athletes is also important for maintaining the wellbeing of the athletes. Therefore, it is essential for coaches and sports organizations to invest in providing social support to coaches, given the competitive and challenging environment they operate in, which can lead to negative situations affecting the wellbeing of sports coaches. The study conducted highlights the limited scientific production on the social support of coaches, making it crucial to increase research in this area. The methodologies used stem from research paradigms in psychology, necessitating the development of a new conceptual framework that integrates social variables and blends quantitative and qualitative research methods.

The reviewed studies emphasize the need for coaches and sports club organizational structures to pay attention to this dimension of coaches' social support. It is the professional responsibility of coaches to ensure support and guidance in their profession. The special attention of family members, athletes, managers, and others to the actions of the coach is crucial for the success of the sports project at hand.

In conclusion, this systematic review underscores the significance of social support for coaches in various aspects of their personal and professional lives. It highlights the positive outcomes associated with social support and the potential drawbacks of its absence. As coaching is a demanding profession, understanding and enhancing social support systems can contribute to the wellbeing of coaches and, subsequently, the success of sports endeavors. Further research and the development of comprehensive support frameworks are essential to address the multifaceted nature of social support in the context of sports coaching.

5 Practical implications

The study presents important contributions on how sports coaches perceive different types of social support provided by various agents (i.e., family members, peers, and friends), as well as the consequences that social support will have on various aspects of the coach's life (e.g., wellbeing). Future studies related to this topic could focus on: samples of sports coaches from different regions/countries, understanding how the cultural factor may affect the consequences of social support provided by different agents on coaches' wellbeing; dividing the sample of coaches into male sports and female sports, following the trend of increasing female athletes in sports and creating knowledge associated with this evolution; dividing the sample of sports coaches by age groups, understanding how social support provided by different agents impacts the wellbeing of coaches of different ages. Thus, important conclusions can be drawn to help sports coaches make better use of social support, aiming to improve their general wellbeing and, consequently, their performance.

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.

Author contributions

JF: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. FR: Writing – original draft. PS: Investigation, Writing – review & editing. MS: Conceptualization, Writing – review & editing. FS: Conceptualization, Writing – review & editing. GC: Formal analysis, Methodology, Writing – review & editing. AH: Writing – original draft, Writing – review & editing. JR: Conceptualization, Investigation, 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.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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EDITED BY
Manuel Gómez-López,
University of Murcia, Spain

REVIEWED BY
Pierluigi Diotaiuti,
University of Cassino, Italy
Francisco Serrano Romero,
Manukau Institute of Technology, New Zealand

*CORRESPONDENCE
Aochuan Xue
✉ 1478470940@qq.com

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The effect of exercise motivation on college students' self-efficacy: the mediating roles of leisure satisfaction and mental toughness

Chengfeng Yu[1], Zhaohong Zeng[2], Aochuan Xue[3]* and Qianjin Wu[1]

[1]School of Physical Education, Shandong University, Jinan, Shandong, China, [2]School of Sports and Health, Zunyi Medical University, Zunyi, Guizhou, China, [3]School of Physical Education and Health, East China Normal University, Shanghai, China

Background: The theory of motivation suggests that individual motivation is moderately stimulated to drive individuals to engage in the behaviors for which they are motivated. It is therefore that the moderate stimulation of exercise motivation will likely lead to the enhancement of college students' participation in exercise.

Objective: Investigate the effect of exercise motivation on college students' self-efficacy, reveal the mediating role of leisure satisfaction and mental toughness, and provide empirical evidence improving college students' self-efficacy through exercise motivation.

Methods: A stratified whole-sample approach was employed to survey 715 college students, based on a correlation table with good reliability and validity. Scale items were designed to collect subjects' exercise motivation, self-efficacy, leisure satisfaction, and mental toughness in the study context. Mediation effect analyses were carried out using SPSS and AMOS.

Results and conclusion: A significant positive effect of exercise motivation on self-efficacy ($\beta = 0.18$, $p < 0.001$), leisure satisfaction ($\beta = 0.50$, $p < 0.001$), and mental toughness ($\beta = 0.45$, $p < 0.001$). Leisure satisfaction and mental toughness had a significant positive effect on self-efficacy ($\beta = 0.40$, $p < 0.001$; $\beta = 0.30$, $p < 0.001$). Furthermore, leisure satisfaction and mental toughness significantly mediated in exercise motivation and self-efficacy. In conclusion, our findings further explored the effects of exercise motivation on college students' self-efficacy and revealed the mediating roles of leisure satisfaction and mental toughness.

KEYWORDS

exercise motivation, self-efficacy, leisure satisfaction, mental toughness, structural equation modeling

1 Introduction

Motivation is the intrinsic psychological tendency or internal drive that inspires and sustains an individual's actions and directs them toward a certain goal, and it is the intrinsic motivation that determines behavior (Bandhu et al., 2024; Cook and Artino, 2016). Intrinsic motivation, in particular, plays a significant role in determining human behavior. Exercise

motivation (EM) can be defined as the intrinsic or extrinsic motivation that prompts individuals to engage in sports activities (Barkoukis et al., 2024; Zhu et al., 2024). This motivation can be derived from the individual's intrinsic needs, desires, or values, or it can be influenced by external factors such as rewards, social pressures, or expectations (Deci and Ryan, 2013; Deci et al., 2001). Motivation derived from the pursuit of achievement, health, socialization, and other factors can significantly impact the motivation, persistence, and quality of performance of individuals engaged in sporting activities.

Self-efficacy can be defined as an individual's subjective judgment about their capacity to perform a specific action to attain a desired outcome (Schunk, 1995; Bandura, 1991). It encapsulates the individual's belief in their capability to execute a given action in order to achieve a particular purpose. The self-efficacy theory posits that self-efficacy can influence behavior, and that behavior can also influence self-efficacy (Jia and Wang, 2024; McLaren et al., 2024; McLaren et al., 2023). Furthermore, individuals with high self-efficacy demonstrate elevated levels of self-confidence and greater adherence to behavioral expectations in the context of diverse challenges and difficulties (Rafiei et al., 2024). The efficacy beliefs of college students are shaped by a combination of past experiences, personal attributes, and social support, which in turn influence their engagement in sporting activities. In examining the impact of sports motivation on self-efficacy, it is essential to consider the potential mediating influence of an individual's intricate intrinsic motivational factors.

A study conducted by Kavussanu and Roberts (1996) on college students who were beginning to play tennis revealed that, among males, mastery of the motivational climate was a significant predictor of self-efficacy. In contrast, among females, the strongest predictor was motivation for performance. In a survey conducted by Pauline (2013) of 871 undergraduate students, it was found that gender differences in self-efficacy were equally influential with regard to college students' physical activity behaviors and motivation to exercise. Males were observed to be more confident and self-protective in undertaking challenging physical activity, whereas females needed help from others in developing an exercise regimen in order to be able to further exercise (Pauline, 2013). In light of the aforementioned theories and related literature, this study puts forth hypothesis:

> *H1*: Exercise motivation has a significant positive effect on college students' self-efficacy.

Leisure satisfaction through exercise activities can be defined as a positive emotional state resulting from the engagement in or selection of leisure activities (Beard and Ragheb, 1980; Teno et al., 2024). It represents the extent to which individuals experience satisfaction with their leisure experience or situation. It is evident that physical and recreational sports play an instrumental role in shaping the self-perception and psychological well-being of college students. These activities not only bolster physical vitality but also facilitate social interactions and mental growth. A study conducted by Lee, Gun-Chur et al. revealed a positive correlation between college students' motivation to engage in sports and their overall satisfaction with their college experience. This was determined through a comprehensive survey and analysis of 419 college students who participated in recreational sports (Lee, 2019). The study conducted by Wu et al. (2021) on a sample of secondary school students in Chengdu, Sichuan Province, China, demonstrated a significant positive correlation between leisure motivation and leisure satisfaction. In light of the aforementioned evidence, this paper proposes the research hypothesis:

> *H2*: Exercise motivation significantly and positively effects college students' leisure satisfaction.
>
> *H3*: Leisure satisfaction significantly and positively effects college students' self-efficacy.
>
> *H4*: Leisure satisfaction mediates the influence of exercise motivation on college students' self-efficacy.

Mental toughness is a dynamic process in which life events, such as stress and adversity, act simultaneously with protective factors (Richardson et al., 1990; Li et al., 2024). In the context of competitive sports, mental toughness is regarded as a pivotal factor in an athlete's capacity to navigate the inherent pressures of competition and rebound from setbacks. Athletes who demonstrate elevated levels of mental toughness tend to exhibit superior performance under pressure and demonstrate accelerated recovery from suboptimal outcomes. Prior empirical studies have demonstrated a robust positive correlation between mental toughness and self-efficacy (Ali et al., 2024). Athletes with higher self-efficacy are more likely to develop resilience, which enables them to cope more effectively with stress and challenges. Furthermore, participation in enjoyable leisure activities (higher leisure satisfaction) has been demonstrated to enhance an individual's capacity to effectively cope with stressors encountered during sporting activities (Freire and Teixeira, 2018; Pressman et al., 2009). This may be attributed to the fact that individuals who report high levels of leisure satisfaction tend to exhibit superior mental toughness (Terzi et al., 2024). In light of the above, this paper puts forth the research hypothesis:

> *H5*: Exercise motivation significantly and positively effects mental toughness in college students.
>
> *H6*: Mental toughness significantly and positively effects self-efficacy among college students.
>
> *H7*: Mental toughness mediates the effect of motivation on self-efficacy among college students.

In recent years, researchers at home and abroad have engaged in impassioned debate regarding the motivations of college students to participate in sports. However, it is equally important to focus on the reasons for these motives and their impact on college students, both physically and psychologically. Accordingly, this study employs college students as the research object to investigate the impact of sports motivation on college students' self-efficacy and to elucidate the mediating role of leisure satisfaction and human mental toughness. The mediation model, which synthesizes the research hypotheses, is presented in Figure 1.

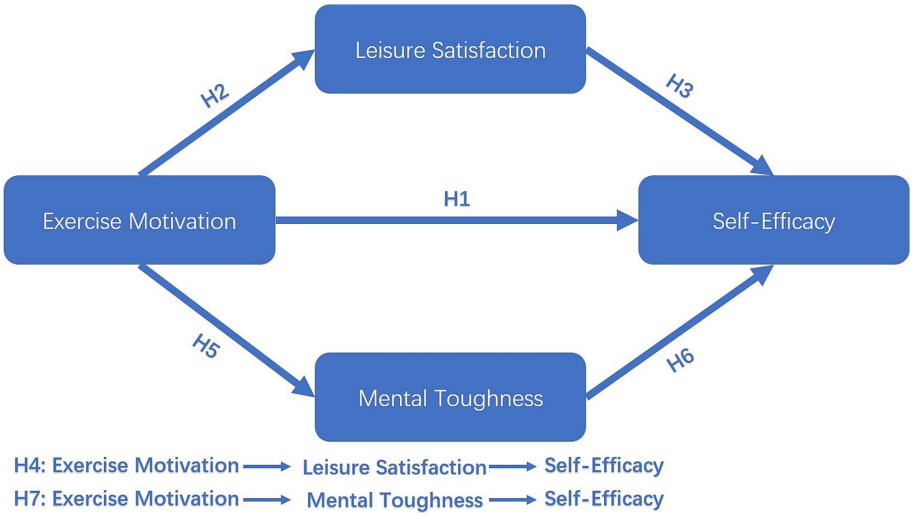

FIGURE 1
Conceptual model proposed in this study.

TABLE 1 Exercise Motivation Scale.

Serial number	Measurement items
EM1	Because it allows me to learn more about my favorite sport.
EM2	Because of the pleasure I get from learning sports skills, I've never tried before.
EM3	Because I feel a great sense of personal satisfaction when I master certain difficult sports techniques.
EM4	Because of the pleasure I feel in identifying and correcting my own shortcomings.
EM5	Because of the joy I felt in the exciting experience of the sport.
EM6	Because I love the feeling of being totally immersed in a sport.

2 Methods

2.1 Participants

The participants in this study were selected from among students enrolled in four undergraduate colleges in Shandong Province. A total of 720 questionnaires were distributed online, and 715 valid questionnaires were obtained after data cleaning and the removal of invalid questionnaires. The questions of the Exercise Motivation Scale, Leisure Satisfaction Scale, Mental Toughness Scale, and Self-Efficacy Scale were based on the Likert five-point scale, with 1 indicating a strong disagreement and 5 indicating strong agreement. The quantitative data obtained were employed as the foundation for the empirical analyses.

2.2 Data collection

2.2.1 Exercise Motivation Scale

In order to meet the requirements of this study, the Behavioral Motivation Scale for Physical Education (BRPEQ) was modified and subsequently employed to investigate motivation for physical education. The BRPEQ is based on the Dutch SREQ-1, which was revised and renamed BRPEQ by various scholars in subsequent studies. As illustrated in Table 1, the scale was employed to examine the motivation of students to engage in physical education across five dimensions, encompassing internal motivation, identity regulation, external regulation, and a lack of motivation (Biese et al., 2024). The scale was scored on a 5-point Likert scale, with 1 indicating a high level of non-compliance and 5 indicating a high level of compliance.

2.2.2 Leisure Satisfaction Scale

The Leisure Satisfaction Scale (LSS) is a psychometric instrument designed to assess the degree of satisfaction derived by an individual from engaging in leisure activities. The scale was initially developed by scholars such as Beard (Beard) and Ragheb (Ragheb) and has undergone multiple revisions and validations (Trottier et al., 2002). In order to align with the specific requirements of this study, the Leisure Satisfaction Scale was modified and subsequently employed in the survey, with reference to the adapted and validated version of the scale in the Chinese context. The content validity of the questionnaire was evaluated through an expert survey, and the results demonstrated a high level of validity. As shown in Table 2, the scale comprises 11 items, which have been grouped into six principal dimensions: psychological, educational, social, relaxation, physical, and aesthetic. The scale was scored on a 5-point Likert scale, with 1 indicating a response that was "very non-compliant" and 5 indicating a response that was "very compliant."

2.2.3 Mental Toughness Scale

In order to align with the requirements of this study, the Sports Attitude Questionnaire (SAQ) from the previous study was revised. As shown in Table 3, the revised scale encompasses five dimensions: concentration, emotional control, positive cognition, family support, and interpersonal collaboration. The content validity of the questionnaire was also evaluated through an expert survey, and the results demonstrated a high level of validity (Nartova-Bochaver et al., 2021).

TABLE 2 Leisure Satisfaction Scale.

Serial number	Measurement items
LS1	My sports and leisure activities give me confidence.
LS2	My sports and leisure activities give me a sense of achievement.
LS3	My sports and leisure activities increase my awareness of my surroundings.
LS3	My sports and leisure activities provide me with the opportunity to try new things.
LS5	My sports and leisure activities help me to understand others.
LS6	I interact socially with others through sports and leisure activities.
LS7	My sports and leisure activities help me to find my soul mate.
LS8	My sports and leisure activities help me to relax.
LS9	My sports and leisure activities make me happy.
LS10	My physical recreational activities help me stay healthy.
LS11	I engage in recreational sports activities in places that interest me.

TABLE 3 Mental Toughness Scale.

Serial number	Measurement items
MT1	I can achieve my athletic goals.
MT2	I will not be discouraged by failure.
MT3	I like to seek new challenges in sports.
MT4	I feel empowered by the difficulties I encounter in sports.
MT5	I am able to concentrate and think clearly under the pressure of difficult situations.
MT6	I can make unusual or difficult decisions when developing an exercise program.
MT7	I can adapt to the internal and external changes that occur during exercise.
MT8	My past successes have given me the confidence to face the challenges of the sport.
MT9	After experiencing instances of competition or sports injuries, I tend to recover quickly.
MT10	When the movement is in trouble, I know where to go for help.
MT11	I feel in control of my athletic life.

2.2.4 Self-Efficacy Scale

The concept of self-efficacy theory concerns an individual's subjective evaluation of their capacity to perform a specific behavior. This evaluation, in turn, serves to enhance the individual's motivation to act in a manner that leads to an improvement in their psychological state and self-confidence. The scale was developed by the German psychologist Ralph Schwarzer and his colleagues in 1981 and was selected for revision according to the requirements of this study, as shown in Table 4. It was subsequently used in the survey (Steigen et al., 2022).

TABLE 4 Self-Efficacy Scale.

Serial number	Measurement items
SE1	If I do my best, I'll always be able to finish even the most difficult sports.
SE2	Even when people questioned me, I was able to stick to the sport I wanted to do.
SE3	For me, sticking to my ideals and reaching my athletic goals is a sure thing.
SE4	I'm confident that I can effectively deal with anything that comes out of the blue in sports.
SE5	With my talents, I'll be able to handle the unexpected in sports.
SE6	If I put in the necessary effort, I'm bound to be able to solve most of the puzzles in sports.
SE7	I can face the difficulties of sports with equanimity because I believe in my ability to handle things.

2.3 Statistical analysis

IBM SPSS Statistics 26.0 was used for descriptive analysis of relevant variables, correlation analysis, and AMOS was also used to analyze the mediating effects of leisure satisfaction and mental toughness between exercise motivation and self-efficacy; Cronbach's alpha coefficients and validation factor analyses were used for the reliability tests, respectively. In this study, a total scale containing all items was established, and in order to ensure that the internal consistency of the scale was guaranteed, the internal consistency reliability coefficients of the scale were tested for internal consistency with Cronbach's α values before conducting the validation factor analysis. In the event that the correlation between the item and the dimension is low, and the overall reliability of the remaining items in the dimension is significantly enhanced following their removal, the item is deleted. In order to verify the structural model and data fitting, the following statistical indices were employed in the Structural Equation Modeling (SEM) analysis: Chi-square, df, Chi-square/df, GFI, CFI, and AGFI.

3 Results

3.1 Reliability and validity

As demonstrated in Table 5, the Cronbach's α coefficient value of each variable exceeds 0.7, indicating that each measurement model exhibits good internal consistency reliability. Furthermore, the variables have been tested for validity. The factor loadings of all items are greater than 0.7, and the AVE values of the latent constructs are essentially greater than 0.5, indicating that each measurement model has good convergent validity. As illustrated in Table 6, with regard to discriminant validity, the square root of the AVE values of all potential constructs is greater than the correlation coefficient between the potential construct and any other potential construct, thereby indicating that each measurement model has good discriminant validity.

3.2 Structural equation modeling analysis

In this study, Amos data processing software was employed to ascertain the statistical significance of path coefficients. As illustrated in Figure 2, the findings revealed that exercise motivation exerted a statistical positive influence on self-efficacy ($\beta = 0.18$, $p < 0.001$) and on

TABLE 5 Cronbach's α values and factor loadings, CR and AVE for each item.

Variable	Item	Loadings	Cronbach's α	CR	AVE
Exercise motivation	EM1	1.02	0.877	0.877	0.542
	EM2	1.02			
	EM3	1.02			
	EM4	0.91			
	EM5	0.99			
	EM6	1.00			
Leisure satisfaction	LS1	1.00	0.932	0.932	0.556
	LS2	0.95			
	LS3	0.88			
	LS4	0.85			
	LS5	0.95			
	LS6	0.92			
	LS7	0.90			
	LS8	0.86			
	LS9	0.90			
	LS10	0.92			
	LS11	0.95			
Mental toughness	MT1	1.07	0.929	0.929	0.542
	MT2	1.03			
	MT3	0.99			
	MT4	1.11			
	MT5	1.03			
	MT6	1.04			
	MT7	1.07			
	MT8	1.00			
	MT9	0.99			
	MT10	1.01			
	MT11	1.00			
Self-efficacy	SE1	1.00	0.897	0.893	0.544
	SE2	1.07			
	SE3	1.00			
	SE4	0.97			
	SE5	1.00			
	SE6	0.95			
	SE7	1.01			

leisure satisfaction ($\beta = 0.50$, $p < 0.001$). Furthermore, exercise motivation was found to have a significant positive effect on mental toughness ($\beta = 0.45$, $p < 0.001$). Additionally, leisure satisfaction was observed to have a significant positive effect on self-efficacy ($\beta = 0.40$, $p < 0.001$), while mental toughness was also found to have a significant positive effect on self-efficacy ($\beta = 0.30$, $p < 0.001$). In light of the aforementioned evidence, it can be concluded that H1, H2, H3, H4, and H5 are supported.

As shown in Table 7, in terms of mediating effects, the direct, indirect, and total effects between exercise motivation, leisure satisfaction, mental toughness, and self-efficacy were measured using the mediating effects analysis procedure in the Amos data analysis software. First, in the path relationship "motivation → leisure satisfaction → self-efficacy," the direct effect was significant, the indirect effect was significant, and there was a full mediation effect. In addition, in the path relationship 'motivation → mental toughness → self-efficacy,' the direct effect was significant, the indirect effect was significant, and there was a complete mediation effect. In conclusion, hypotheses H6 and H7 are supported.

4 Discussion

The aim of this study was to investigate the effects of exercise motivation on the self-efficacy of college students. To this end, a questionnaire survey was conducted among college students in Shandong Province, which revealed the mediating roles of leisure satisfaction and mental toughness. The results show that exercise motivation has a direct effect on self-efficacy, while leisure satisfaction and mental toughness play a significant mediating role in the relationship between exercise motivation and self-efficacy.

Motivation represents an intrinsic catalyst for an individual to accomplish a task and is the primary driver of individual behavior (Deci et al., 1991; Ryan and Deci, 2000). Those who are highly motivated to engage in physical activity tend to exhibit a heightened sense of self-efficacy, which can be defined as the belief in one's ability to complete a task successfully (Boonekamp et al., 2020; Zhang et al., 2012; Jain et al., 2021). Individuals who engage in physical activity for its own sake are more likely to experience an enhanced sense of self-efficacy, which not only enables them to effectively complete their exercise regimen but also fosters a sense of self-efficacy and competence that extends beyond the immediate exercise session (Pekmezi et al., 2009). This is in accordance with Bandura's (1997) self-efficacy theory, which posits that it is more straightforward to cultivate and sustain a high level of self-efficacy when engaging in activities that are enjoyable. It can be reasonably deduced that in order to successfully increase the number of individuals participating in exercise, it is necessary to place emphasis on enhancing their intrinsic motivation. This may be achieved by the implementation of diverse, engaging, and challenging exercise programs, which will stimulate individuals' interest and enthusiasm. Concurrently, the development of individuals' self-efficacy through the setting of small, achievable goals and the provision of positive feedback and support can also markedly enhance their motivation and participation (Plotnikoff et al., 2013). This study lends support to the positive correlation between exercise motivation and self-efficacy, thereby underscoring the pivotal role of intrinsic motivation and self-efficacy in fostering exercise behavior. These findings not only enhance the theoretical foundation of exercise psychology but also provide crucial guidance for practice, enabling the design of more effective exercise intervention strategies.

It is important to consider the role of leisure satisfaction in this study, and the results indicate that leisure satisfaction plays a significant mediating role in exercise motivation and self-efficacy. It has been previously highlighted that there is a positive correlation between exercise motivation and leisure satisfaction. However, no study has yet proposed that the pathway EM → LS → SE is viable. This study, therefore, represents a significant contribution to the field, confirming for the first time

TABLE 6 Discriminant validity of reflective measurement models.

	Exercise motivation	Leisure satisfaction	Mental toughness	Self-efficacy
Exercise motivation	**0.736**			
Leisure satisfaction	0.486	**0.746**		
Mental toughness	0.427	0.462	**0.736**	
Self-efficacy	0.488	0.608	0.54	**0.738**

The diagonal line is the square root of the AVE value for each potential construct, and the rest are the correlation coefficients between potential constructs.

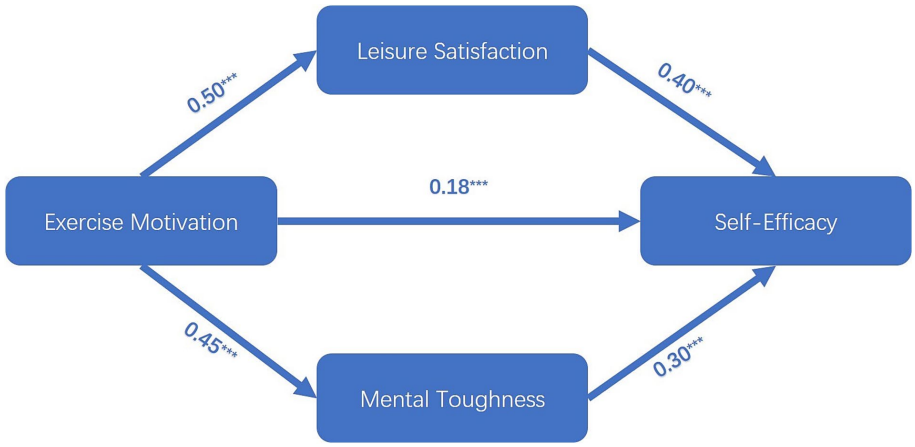

FIGURE 2
Effect of exercise motivation on self-efficacy through rest satisfaction and mental toughness (Chi-square = 924.131, df = 555, Chi-square/Df = 1.655, GFI = 0.932, CFI = 0.974, AGFI = 0.923). ***$p < 0.001$.

TABLE 7 Results of the mediation effect.

Variable	Point estimate	Product of coefficient		Bootstrapping			
		SE	Z	Bias-corrected 95% CI		Percentile 95% CI	
				Lower	Upper	Lower	Upper
IE	0.33	0.039	0.001	0.26	0.409	0.261	0.409
SM → LS → SE	0.199	0.03	0.001	0.141	0.261	0.143	0.261
SM → RL → SE	0.131	0.027	0.001	0.086	0.194	0.084	0.189
DE	0.174	0.058	0.001	0.065	0.29	0.064	0.29
TE	0.504	0.053	0.001	0.399	0.607	0.401	0.611

that exercise motivation can modulate self-efficacy through the mediating variable of leisure satisfaction. Consequently, while we focus on enhancing self-efficacy through exercise motivation, we can also consider the role of leisure satisfaction and mental toughness. It may be the case that a more optimal program can be identified. This is consistent with the findings of other researchers that self-efficacy moderates the relationship between task-oriented motivational climate and satisfaction. However, it differs from this paper in that collective efficacy mediates the relationship between baseline perceived motivational climate and satisfaction (Blecharz et al., 2014). Moreover, in modeling the mediation relationships, we acknowledge the potential for collinearity effects among the latent variables, particularly given the interdependence between exercise motivation, leisure satisfaction, and mental toughness. Although we were unable to compute specific metrics for multicollinearity in this study, we took care to design the study and select measures in a way that minimizes potential collinearity issues. Future research could benefit from a more detailed examination of this aspect to enhance the understanding of the relationships among these constructs.

In general, an individual's motivation and beliefs regarding the completion of a specific task influence their actual performance and self-perception (Anderson et al., 2007). College students with higher motivation are more likely to feel competent in sports, which subsequently enhances their self-efficacy (Bandhu et al., 2024; Bandura, 1988). Exercise motivation encourages individuals to engage in physical activity and enhances their level of participation (Rahman et al., 2020). The acquisition of a sense of achievement and pleasure in sports has been demonstrated to increase self-efficacy. In particular, the attainment of goals in

sports serves to reinforce this sense of achievement, which in turn enhances self-efficacy. These findings have significant implications for educational practice and mental health interventions, particularly in terms of enhancing students' academic and life performance. Educators can enhance students' self-efficacy by encouraging them to engage in physical activity. The implementation of diverse and challenging sports programs enables students to sustain their success and sense of control in sports, thereby enhancing their self-confidence and self-efficacy. Furthermore, college students who demonstrated higher levels of motivation exhibited enhanced leisure satisfaction and mental resilience following exercise (Yang and Qian, 2024; Choi et al., 2020). The observed increase in leisure satisfaction may be attributed to the sense of enjoyment and accomplishment associated with exercise (Wang, 2022). Similarly, the increase in mental toughness may be attributed to the process of encountering challenges and subsequently overcoming them during exercise. These findings are consistent with previous research, which has indicated that exercise has a beneficial effect on both physical and mental health, as well as on overall life satisfaction (Ryan and Deci, 2000). This finding emphasizes the importance of exercise in promoting overall well-being and psychological resilience, thereby reinforcing the necessity to integrate exercise into health promotion programs for college students. In addition, it was found that leisure satisfaction and psychological resilience have a significant positive effect on self-efficacy. It can be posited that elevated levels of leisure satisfaction may serve to augment positive affect and self-confidence, which in turn may lead to an increase in self-efficacy (Tian et al., 2022). Similarly, individuals who demonstrate higher levels of psychological resilience are more adept at coping with stress and challenges, which also contributes to their sense of self-efficacy (Wu et al., 2020; Qin et al., 2023). These findings lend support to the psychological capital theory put forth by Luthans et al. (2007), which posits that psychological resilience and self-efficacy are crucial elements of an individual's positive psychological resources. This study lends further support to this theory, indicating that enhancing psychological resilience and leisure satisfaction represents an effective strategy for enhancing self-efficacy. It is of greater significance to note that our research has validated the mediating function of leisure satisfaction and mental toughness in the relationship between exercise motivation and self-efficacy. In particular, the motivation to exercise indirectly enhances self-efficacy by increasing individuals' satisfaction with their leisure activities and psychological resilience. In line with the findings of Diotaiuti et al. (2023), which highlight the role of psychological mechanisms such as decentering in athletes, our study further explores how leisure satisfaction and mental toughness mediate the relationship between exercise motivation and self-efficacy in college students (Diotaiuti et al., 2023). This finding contributes to the theoretical frameworks of sports psychology and educational psychology by emphasizing the pivotal role of leisure satisfaction and mental toughness in the psychological development of individuals. The identification of these two variables as mediators allows us to elucidate the specific mechanisms through which exercise motivation affects self-efficacy. Furthermore, it provides clear targets for future interventions.

4.1 Limitations

This paper presents the findings of an investigation into the mechanism through which sports motivation exerts an influence on self-efficacy, which is mediated by leisure satisfaction and mental toughness. The investigation was conducted through a survey of college students who participate in sports in Shandong Province. This study is not without limitations. Firstly, although Shandong is one of China's most populous provinces, the findings may not be representative of the wider Chinese population, potentially affecting the generalisability of the results. Secondly, the survey was conducted with a sample of college students, and therefore the findings cannot be generalized to the general public. Future research could consider longitudinal studies with larger sample sizes to further validate the relationship between sports motivation and self-efficacy. In conclusion, the cross-sectional design of our study precluded the establishment of causal relationships between variables. This is an inherent limitation of the analytical approach employed. To re-examine the causal relationships along each pathway, longitudinal or controlled trials are required.

5 Conclusion

The aim of this study was to examine the effect of exercise motivation on self-efficacy and to explore possible mechanisms. Our results indicate that exercise motivation has a significant positive effect on self-efficacy. Life satisfaction and mental toughness appear to be important mediators between exercise motivation and self-efficacy. One possible explanation is that students may use exercise as a tool to alleviate their poor physical and mental health.

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 Shandong University of 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

CY: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. ZZ: Writing – review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Investigation, Conceptualization. AX: Writing

– review & editing, Writing – original draft, Supervision, Software, Resources, Project administration, Methodology, Investigation, Conceptualization. QW: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Data curation, 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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EDITED BY
David Manzano Sánchez,
University of Extremadura, Spain

REVIEWED BY
Liliana Ricardo Ramos,
Polytechnic Institute of Santarém, Portugal
Juan De Dios Benítez Sillero,
University of Cordoba, Spain

*CORRESPONDENCE
Suh Donghwi
donghwisuh@snu.ac.kr

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Comparison on self-determination, peer-relationship, and alienation in physical education of early adolescent in Korea and China

Jeong Jaeuk[1], Sun Yu[1] and Suh Donghwi[2]*

[1]Department of Physical Education, Seoul National University, Seoul, Republic of Korea, [2]Department of Physical Education, Jeonbuk National University, Jeonju, Republic of Korea

Introduction: In order to identify effective strategies for enhancing a high-quality physical education system, it is imperative to undertake research that examines the nuances of educational culture, specifically focusing on the psychological experiences of early adolescents within physical education classes. This study aims to compare self-determination, peer-relationships, and feelings of alienation in physical education among adolescents from Korea and China, both situated in East Asia, with respect to their nationality and gender.

Methods: One hundred and twenty two early adolescent males (M = 14.34, SD = 0.65) and 78 females (M = 14.34, SD = 0.64) from South Korea and 125 early adolescent males (M = 14.13, SD = 0.58) and 70 females (M = 14.13, SD = 0.59) from China participated in this study, with a mean age of 14.24 ± 0.62. The Academic Self-Regulatory Scale (SRQ-A), Peer-relationship Questionnaire, and a Scale for Measuring Student Alienation in Physical Education were utilized for data analysis. For statistic comparisons, a t-test was used.

Results: Self-determination of male and female students in China was significantly higher than that of male and female students in Korea, respectively. Peer-relationship of male students in Korea was significantly higher than that of male students in China. Physical education alienation of the female students in Korea was significantly higher than that of male students in Korea.

Discussion: Given that the influence of self-determination, peer relationships, and physical education alienation varies by nationality and gender, it is crucial to seek and implement strategies to develop an effective physical education system. By doing so, physical education alienation can be minimized and prevented, ultimately preserving the health and well-being of adolescents. This approach is vital for fostering a supportive and inclusive environment that promotes lifelong fitness and health.

KEYWORDS

self-determination, peer-relationship, physical education alienation, early adolescent, East Asia

Introduction

World Health Organization (WHO) has emphasized that physical, social, and mental health are all essential for human health and happiness (Breslow, 1972). Hence, countries implement various systems to manage public health (Haldane et al., 2021). Adolescence marks a significant stage in human development, and governments support this development through compulsory

education. Among these, physical education plays a crucial role in promoting overall physical, social, and mental well-being (Wallhead and Buckworth, 2004). Numerous studies have shown that regular physical activity improves cardiovascular health, enhances muscular strength, and promotes mental well-being by reducing symptoms of anxiety and depression. Additionally, physical activity fosters social skills and teamwork, contributing to overall social development. For instance, research has demonstrated that adolescents who engage in regular physical activity exhibit better academic performance and higher self-esteem compared to their less active peers (Calfas and Taylor, 1994). These benefits highlight the critical role of exercise in supporting the holistic health and well-being of adolescents. However, ineffective physical education classes can lead to feelings of alienation (Hascher and Hadjar, 2018). This feelings of alienation in learning discourages healthy development among students (Taylor and Adelman, 2020). In general, alienation is defined as a situation in which an individual is not integrated into their relationship with society and feels detached from the overall atmosphere of the classroom, including both pedagogical and sociological aspects (Tolbert et al., 2022). When alienation occurs within the context of physical education, it is referred to as physical education alienation. This term describes a persistent experience of negative emotions that students actively seek to avoid during physical education classes. Various factors lead to the physical education alienation, including environmental factors within the physical education setting, factors related to physical education teachers, factors related to students, and factors related to parents and the surrounding community (Lee et al., 2021). Physical education alienation, especially from the viewpoint of students, is characterized by feelings of pointlessness, helplessness, and isolation as components of the alienation experience (Spencer-Cavaliere and Rintoul, 2012). Hence, physical education alienation is directly influenced by psychological factors inherent in the learners themselves. As physical education classes primarily involve adolescents, it is important to examine various factors that are aligned with the characteristics of adolescents.

Early adolescence is marked by the development of self-identity, a transition from egocentric thinking, and an increasing awareness of others (Kroger, 2006). This age range corresponds to middle school students in Korea and China, typically aged 11–13 (Salmela-Aro, 2011). Early adolescents engage in meaningful interactions with their peers and experience social growth, often by comparing themselves to friends of similar age and developmental stage (Mitic et al., 2021). As a result, various aspects of adolescent psychology develop. Peer relationships refer to interpersonal relationships with peers and have a significant influence on the emotional and social development of adolescents (Brown and Bakken, 2011). Therefore, it is necessary to examine the psychological factor of peer-relationships in the context of the physical education alienation among early adolescents. Peer-relationships encompass sub-factors such as adaptability to peers and sustained interactions, both of which exert significant influence on the social psychological factors of adolescents (Berry et al., 1989; Mikami et al., 2010).

Adolescents, as they observe and learn from their peers, also demonstrate autonomy by applying acquired knowledge. The behavior resulting from this autonomy is referred to as self-determination. The self-determination theory (SDT) posits that comprehending human motivation necessitates acknowledging innate psychological needs for competence, autonomy, and relatedness (Ryan and Deci, 2022). Self-determination theory suggests that higher levels of self-determination are linked with better learning and achievement outcomes, as well as positive psychological effects (Gamble et al., 2023). Conversely, low levels of self-determination can result in weakened intrinsic motivation (Tang et al., 2020) and experiencing negative emotions, potentially leading to feelings of alienation in the classroom (Perlman, 2012). This implies that emotions tied to self-determination are linked with feelings of alienation within the community (Green, 2010). Self-determination is evaluated using a continuum that ranges from external motivation to internal motivation. The level of self-determination is determined using the Academic Self-Regulatory Scale (Levesque et al., 2004).

As mentioned earlier, alienation from physical education significantly impacts peer-relationships and self-determination in adolescents. Unlike other subjects, physical education classes often take the form of team sports, and even individual sports are typically conducted in the proximity of a gymnasium, which inevitably increases awareness of peers. Additionally, in physical education classes, differentiated instruction based on learners' levels is implemented even when teaching the same sport or movement, and various roles are assigned according to individual responsiveness. Therefore, self-determination becomes a crucial factor in physical education classes (Ward et al., 2008).

However, there is limited research exploring physical education alienation, a direct and significant negative psychological factor, in conjunction with the primary characteristics of adolescents. Furthermore, adopting a cross-cultural perspective in research allows for broader insights into what is considered typical and atypical within each culture, as well as facilitates the examination of the universality of concepts (McMullen et al., 2005). Since the outbreak of the Covid-19 pandemic worldwide, research has been conducted on the psychological changes in adolescents within the educational cultures of various countries (Leon-Zarceno et al., 2021; Maugeri et al., 2020; Okuyama et al., 2021; Varea et al., 2022). China was the first country where Covid-19 originated, and Korea is its neighboring country. Analyzing the psychological changes based on the differences in educational cultures between these two nations becomes a crucial social task in preparing future generations. Korean culture places a higher value on interpersonal harmony compared to Chinese culture (Houri et al., 2012; Wadsworth et al., 2008). However, in the context of physical education, perceived peer-relationships have been found to have a greater influence in China compared to Korea (Chen and Lin, 2016). Additionally, cultural differences among members of society may lead to variations in self-determination, and in group-based physical education classes, self-determination and peer relationships can influence feelings of alienation (Kreber, 1998; Lee et al., 2000). Therefore, analyzing the differences in peer-relationships, self-determination, and feelings of alienation in physical education classes resulting from the differing cultures of Korea and China can provide valuable insights into the structure of each country's physical education curriculum. Currently, Korea's physical education curriculum aims to cultivate intrinsic values such as character, whereas China's curriculum focuses on the development of athletic skills and theoretical knowledge in physical education (Xin et al., 2019). After all, Both Korea and China are striving to enhance their competitiveness in the global market, and education plays a pivotal role in achieving this goal. Excellent education is achieved when school education is developed with consideration for self-determination and cultural differences (Guay et al., 2008). Therefore, there is a need for research to analyze the differences in educational

culture between the two countries in order to identify ways to further develop superior education systems. Hence, examining the cultural differences between China and its neighboring country, South Korea, particularly regarding the alienation and self-determination of adolescents in physical education classes, as well as their peer-relationships, is noteworthy. This refers to the psychological state experienced by East Asian adolescents in physical education classes. Such analysis could serve as a guide for future directions in physical education for adolescents in each country. Furthermore, in physical education, the construction an educational system that considers gender is essential due to physical differences. Therefore, there is a need to investigate the psychological states in physical education based on gender in both countries (Yamauchi et al., 2007).

This study focuses on analyzing the psychological aspects of physical education classes among East Asian adolescents, as described above. It aims to summarize and analyze previous research content to delineate future research problems, backgrounds, and research directions in the post-COVID-19 era. In particular, it will provide important data for understanding the content, issues, and students' perceptions of physical education in Korea and China by analyzing how research directions are influenced by the characteristics of the educational environments in both countries. Therefore, the purpose of this study was to compare self-determination, peer-relationships, and alienation in physical education among middle school students from Korea and China, based on gender. This study aims to provide information and insights necessary for designing and planning physical education classes that can promote the health of East Asian adolescents in the post-COVID-19 era. It will achieve this by comparing the self-determination, peer-relationships, and alienation experienced by adolescents in physical education classes, taking into account the cultural context of East Asia.

Research method

Research subjects

In this study, the participants consisted of 200 middle school students (122 males: 14.34 ± 0.65; 78 females: 14.34 ± 0.64) from three schools in South Korea and 195 middle school students (125 males: 14.13 ± 0.58; 70 females: 14.13 ± 0.59) from three schools in China (see Table 1). The required number of subjects was calculated using the G*Power 3.1 program (Effect size: 0.5; α: 0.05; power: 0.80; Total sample size:128). The effect size of 0.5 indicates a medium effect according to Cohen's conventions, which suggests a meaningful difference between the groups being compared. The adopted cut-off values for interpreting the effect sizes were set at 0.2 for small, 0.5 for medium, and 0.8 for large effects, allowing for a clear understanding of the practical significance of the findings. The students attend different middle schools in each country, and three urban schools in both Korea and China were sampled using cluster sampling with stratification. All participants and their parents were asked to read and sign an written informed consent form. This study was approved by local ethical committee (IRB No. 2024-07-040-001). The study was conducted in accordance with the Declaration of Helsinki.

Measurement tool

Self-determination

The questionnaire used to measure self-determination type is derived from the Academic Self-Regulatory Scale (SRQ-A) developed by Levesque et al. (2004). This questionnaire was designed to categorize participants' motivational types based on their level of self-determination. A total of 29 sub-factors, consisting of 29 questions, were partially modified and supplemented (see Supplementary Table S1). In adapting and enhancing the Academic Self-Regulatory Scale, initial modifications involved tailoring item phrasing to better fit the context of this study's target population. Specific adjustments were made to clarify terminology and improve question relevance based on pilot testing feedback. Additionally, supplementary questions were incorporated to expand upon the original sub-factors, allowing for a more nuanced assessment of self-determination types. Following these modifications, reliability analysis was conducted to ensure the validity of the scale. This study utilized a questionnaire grounded in the conceptualization of self-determination theory to identify learners' self-determination types (Deci and Ryan, 2004). The questionnaire employs a six-point Likert scale, ranging from "not at all" (1 point), "disagree" (2 points), "neutral" (3 points), "somewhat agree" (4 points), "agree" (5 points), to "strongly agree" (6 points), assessing levels of asynchrony, extrinsic motivation, imposition, and identification. The five subtypes of regulation and internal regulation are encompassed. The reliability analysis yielded a Cronbach's α value of 0.893. Furthermore, the exploratory factor analysis revealed satisfactory results (KMO = 0.871; Bartlett's test of sphericity, $X^2 = 8353.082$, $p < 0.001$), indicating duplicated items. Ultimately, 20 items representing 3 factors were extracted. Detailed results are presented in Supplementary Table S2. The development of the experimental tools was overseen by two Ph.D. holders in sports psychology.

Peer relationship

To assess the relationship between students, the peer relationship questionnaire was adapted and enhanced (Berry et al., 1989). This scale comprises 20 questions across 4 sub-factors, including friendship, adaptation, trust with friends, and communal life with friends. The questionnaire employs a six-point Likert scale, ranging from "not at all" (1 point), "disagree" (2 points), "neutral" (3 points),

TABLE 1 Participants of middle school students from Korea and China.

National	Gender		Grade			Total
	Male	Female	1	2	3	
Korea (age)	N:122 (14.34 ± 0.65)	N:78 (14.34 ± 0.64)	N:19 (13)	N:94 (14)	N:87 (15)	N:200 (14.34 ± 0.64)
China (age)	N:125 (14.13 ± 0.58)	N:70 (14.13 ± 0.59)	N:22 (13)	N:125 (14)	N:48 (15)	N:195 (14.13 ± 0.58)
Total (age)	N:247 (14.24 ± 0.63)	N:148 (14.24 ± 0.62)	N:41 (13)	N:219 (14)	N:135 (15)	N:395 (14.24 ± 0.62)

"somewhat agree" (4 points), "agree" (5 points), to "strongly agree" (6 points). In adapting and enhancing the peer relationship questionnaire, an initial review of the original items was conducted to ensure cultural relevance and appropriateness for the target population. Modifications were made to align the questions with the specific characteristics of the student demographic. This involved rephrasing certain items for clarity and incorporating feedback from pilot testing to refine question wording and structure. Furthermore, reliability analysis was conducted to identify redundant or low-performing items. Based on these findings, exploratory factor analysis was used to confirm the structure of the questionnaire and to retain only items that demonstrated strong factor loadings, thus ensuring the scale's validity and reliability for the final assessment. Following exploratory factor analysis (KMO = 0.753; Bartlett's test of sphericity, $X^2 = 1596.583$, $p < 0.001$), duplicated items were identified. Ultimately, 10 items representing 3 factors were extracted (Supplementary Table S3).

Physical education alienation

To assess physical education alienation, the questionnaire titled 'Development of Scale for Measuring Student Alienation in Physical Education' was utilized, with consultation from two Ph.D. holders in sports psychology (Kim, 2005). The questionnaire was adapted and augmented to be appropriate for middle school students in both China and Korea. To adapt and enhance the original scale for middle school students in China and Korea, initial adjustments were made to ensure cultural relevance and age-appropriateness. This process involved rephrasing certain items to improve clarity and readability for early adolescents. Additionally, supplementary items were incorporated to capture a broader range of alienation experiences specific to the physical education context. Feedback from a pilot study informed further refinements, allowing for the removal of ambiguous or redundant questions. Following these modifications, exploratory factor analysis was conducted to confirm the structure and eliminate duplicated or low-performing items, resulting in a refined scale that accurately represents the key dimensions of physical education alienation. The scale comprises seven questions each on physical education alienation and extracurricular activities, along with six questions on athletic ability alienation, friend alienation, and sports alienation, respectively. The questionnaire employs a six-point Likert scale, ranging from "not at all" (1 point), "disagree" (2 points), "neutral" (3 points), "somewhat agree" (4 points), "agree" (5 points), to "strongly agree" (6 points). Following exploratory factor analysis (KMO = 0.736; Bartlett's test of sphericity, $X^2 = 3571.202$, $p < 0.001$), duplicated questions were identified. Ultimately, 18 questions representing 5 factors were extracted. Specific results are presented in Supplementary Table S4.

Research procedure

The questionnaire for this study was distributed directly to the research participants by their physical education teacher. The questionnaires were administered during March 2024. The data were collected through a questionnaire comprising questions about three variables, which were presented sequentially and collected all at once. Students were allotted approximately 15 min to complete the questionnaire, which contained 53 questions.

Data processing

After the questionnaires were collected, they were sorted and assigned numbers. The data were coded and analyzed using SPSS 23.0. The validity and reliability of the questionnaires were assessed through exploratory factor analysis and Cronbach's alpha test. The main analytical methods utilized in this study comprised descriptive statistics, independent samples *t*-tests, and stepwise multiple regression analysis. Differences were analyzed using *t*-tests based on the country variable, with a significance level set at 0.05.

Results

To investigate the differences in self-determination, peer-relationships, and physical education alienation among middle school students in Korea and China based on gender and country, this study employed independent sample *t*-tests. Significant differences were detected in self-determination, peer-relationships, and physical education alienation between genders and countries. As depicted in Table 2, the level of self-determination among Korean students was significantly lower than that among Chinese students ($p < 0.001$). Additionally, both Korean male and female students exhibited significantly lower levels of self-determination compared to their Chinese counterparts ($p < 0.001$ for both male and female students). The gender differences were as follows: self-determination among male Korean students was significantly higher than among female Korean students ($p < 0.05$). However, among Chinese students, there was no significant difference in self-determination based on gender.

As depicted in Table 3, the peer-relationship among total Korean students was significantly higher than that among Chinese students ($p < 0.001$). According to gender, only male Korean students exhibited

TABLE 2 Self-determination according to country and gender.

Country	Korean male (*n* = 122) Korean female (*n* = 78) Korea total (*n* = 200)		Chinese male (*n* = 125) Chinese female (*n* = 70) Chinese total (*n* = 195)			
	M	SD	*M*	SD	*t*	Cohen's d
Male	65.369	15.943	74.504	16.182	−4.450***	−0.566
Female	60.231	14.908	71.200	15.529	−4.352***	−0.717
Total	63.365	15.748	73.318	16.029	−6.209***	−0.625
Gender	**Korean male (*n* = 122) Chinese male (*n* = 125)**		**Korean female (*n* = 78) Korean female (*n* = 78)**			
	M	SD	*M*	SD	*t*	Cohen's d
Korean	65.369	15.943	60.231	14.908	2.268*	0.329
Chinese	74.504	16.182	71.200	15.529	1.380	0.209

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

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TABLE 3 Peer-relationship according to country and gender.

Country	Korean male (n = 122) Korean female (n = 78) Korea total (n = 200)		Chinese male (n = 125) Chinese female (n = 70) Chinese total (n = 195)			
	M	SD	*M*	SD	*t*	Cohen's d
Male	24.951	5.629	22.176	5.607	3.881***	0.388
Female	26.487	5.167	25.271	6.474	1.260	0.207
Total	25.550	5.505	23.287	6.116	3.858***	0.388
Gender	**Korean male (n = 122) Chinese male (n = 125)**		**Korean female (n = 78) Korean female (n = 78)**			
	M	SD	*M*	SD	*t*	Cohen's d
Korean	24.951	5.629	26.487	5.167	−1.933	−0.280
Chinese	22.176	5.607	25.271	6.474	−5.463***	−0.565

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

TABLE 4 P.E. Alienation according to country and gender.

Country	Korean male (n = 122) Korean female (n = 78) Korea total (n = 200)		Chinese male (n = 125) Chinese female (n = 70) Chinese total (n = 195)			
	M	SD	*M*	SD	*t*	Cohen's d
Male	43.844	10.689	43.512	8.097	0.275	0.035
Female	47.167	7.565	45.100	9.075	1.500	0.247
Total	45.140	9.753	44.082	8.517	1.147	0.115
Gender	**Korean male (n = 122) Chinese male (n = 125)**		**Korean female (n = 78) Korean female (n = 78)**			
	M	SD	*M*	SD	*t*	Cohen's d
Korean	43.844	10.689	47.167	7.565	−2.378*	−0.345
Chinese	43.512	8.097	45.100	9.075	−1.251	−0.187

*$p < 0.05$.

significantly higher peer-relationships than male Chinese students ($p < 0.001$). The gender differences were as follows: There were no differences in peer-relationships among Korean students based on gender. However, among Chinese students, male students exhibited significantly lower peer-relationships compared to female Chinese students ($p < 0.001$).

As depicted in Table 4, there were no significant differences in physical education alienation between the two countries. The gender differences were as follows: Physical education alienation among male Korean students was significantly lower than among female Korean students ($p < 0.05$). However, among Chinese students, there was no significant difference in physical education alienation based on gender.

Discussion

In summary, Chinese students scored higher in self-determination than Korean students for both male and female groups. For peer-relationships, Korean male students scored higher than Chinese male students, while in terms of P.E. alienation, Korean female students scored higher than Korean male students. Effect sizes were calculated for all comparisons to provide a better understanding of the practical significance of the results. Cohen's d was used to assess the magnitude of differences, with cut-off values following Cohen's guidelines: small effects ($d = 0.2$), medium effects ($d = 0.5$), and large effects ($d = 0.8$). For each significant finding, Cohen's d value was calculated and presented in the tables (Tables 2–4). In this study, effect sizes ranged from −0.717 to 0.388. The negative effect size values indicate that, for certain comparisons, the mean of one group was lower than the other, while positive values indicate the opposite. These results suggest mostly small to medium effects. This indicates that while statistical significance was achieved, the practical significance varies depending on the strength and direction of the observed effect sizes (Schäfer and Schwarz, 2019).

When comparing between the two countries, the self-determination of Chinese students was higher than that of Korean students, while the peer-relationship of Korean students was higher than that of Chinese students. This is likely attributed to previous research findings indicating differences in the types of sports experienced by Korean and Chinese students, as well as lower levels of interpersonal relationships among Chinese students compared to Korean students (Houri et al., 2012; Wadsworth et al., 2008). In other words, Korean adolescents who prioritize interpersonal harmony tend to have higher levels of peer-relationships, whereas Chinese adolescents who prioritize individual values tend to have higher levels of self-determination. This could be interpreted as a reflection of national cultural differences concerning interpersonal relationships (Blanchard et al., 2009; Gay, 2013).

Additionally, Korea has a curriculum designed to foster core competencies such as character through physical activity (Xin et al., 2019). Therefore, it is possible that peer-relationships, which are considered one of the core competencies, appear higher among Korean students compared to Chinese students. In China, a curriculum is implemented to cultivate core competencies through athletic skills and health knowledge. Therefore, it can be interpreted that there is a high level of self-determination among Chinese students as they strive to improve their athletic skills and health knowledge. From this perspective, it could be inferred that implementing physical education classes emphasizing self-determination may be effective for students in Chinese culture, while promoting peer-relationships may be beneficial for students in Korean culture, which emphasizes mutual learning styles (Morgan, 2017).

About gender differences in Korea, male students exhibit higher levels of self-determination compared to female students, while female students in Korea experience higher levels of physical

education alienation than their male counterparts, consistent with findings from several previous studies. This is attributed to the fact that gender stereotypes of masculinity and femininity in Korea are reflected in young adolescents' participation in sports (You et al., 2021). This implies that physical activity and sports participation are perceived as more suitable for boys. This leads male students to develop relatively strong athletic abilities due to their physical characteristics and the social atmosphere, which fosters a sense of competence (Joong-gil, 2012). Male students in small clubs engage in active communication both within club sports and online gaming communities. Club activities foster intricate and enduring relationships not only within the campus but also beyond the school grounds (Cho and Choi, 2015). In contrast, in China, female students exhibited higher levels of peer relationships compared to male students, consistent with previous research findings. According to previous research, the low peer relationships among Chinese male students are associated with high levels of aggression (Chen et al., 2012). Therefore, given that the peer relationships of Chinese male students were relatively lower than those of Chinese female students, it is important to consider implementing sports programs in the form of team sports, which can enhance peer relationships (Danioni and Barni, 2019), and addressing issues of aggression through physical activity (Koc, 2017). As schools resume face-to-face classes following the coronavirus pandemic, it is crucial to monitor mental health through peer relationships (Zhu et al., 2022). In particular, it has been reported that peer relationships resulting from physical activity have a greater impact on academic achievement for Chinese male students compared to Chinese female students (Bi et al., 2022; Li et al., 2020). Therefore, designing physical education programs that take these variables into consideration will be effective in promoting the value of human co-prosperity through education. Thus, it is important to consider these factors when organizing physical education classes based on gender and culture. Hence, future research should investigate whether designing classes that consider various psychological factors of Korean and Chinese students, such as self-check or reciprocal styles, promote positive experiences in physical education settings (Chatoupis, 2018; Hein et al., 2012).

Given that psychological well-being and optimal functioning are associated with internal motivation, it is important to plan physical education classes with consideration of cultural characteristics such as self-determination and peer relationships, which significantly impact early adolescence (White et al., 2021). Hence, to enhance self-determination and peer relationships, it would be beneficial to actively incorporate new sports, diversify physical education programs, adjust the level of difficulty, and utilize modified games (Wang et al., 2020). It is believed that the development and supplementation of various physical education programs are necessary to alter the perception of physical education, which has traditionally been focused mainly on male students (Kwon and Block, 2017; Corr et al., 2019). Meanwhile, Jeong et al. (2014) analyzed the phenomenon of students' alienation in physical education to explore strategies for addressing it. The causes of physical education alienation included individual physical ability, negative experiences in physical education, interpersonal factors, class content, and classroom environment. As physical education alienation impacts self-determination, it is important to ensure that physical education classes are well-structured (Kreber, 1998; Lee et al., 2000). Since higher self-determination is associated with higher social problem-solving ability (Lee et al., 2000), well-structured physical education can contribute to fostering a positive social culture.

Additionally during the COVID-19 pandemic, Korea and China implemented different policies and social distancing measures, which may have affected the experiences of adolescents in unique ways. In Korea, strict social distancing and periodic school closures might have influenced peer relationships as students had less face-to-face interaction. This could result in heightened peer-relationship scores once in-person classes resumed, as students were more eager to rebuild connections. In contrast, China's emphasis on rapid containment measures and a focus on online learning might have encouraged students to become more self-reliant, potentially contributing to higher levels of self-determination. The varied COVID-19 measures might also have influenced how students perceive P.E. classes. Korean students, having experienced significant social limitations, may have found P.E. classes a valuable outlet for socialization, whereas Chinese students may have engaged more in individual sports during the pandemic, fostering a sense of personal achievement and autonomy. These contextual factors highlight the importance of considering how differing national responses to COVID-19 may indirectly shape adolescents' educational and social experiences. This allowed us to comprehend the experiences of adolescents in physical education and their psychological states, influenced by the diverse cultures and societal perceptions of gender in Korea and China. This represents a novel approach to adolescent health education within the education system, considering the cultural and social contexts of East Asia in the post-COVID-19 era.

While demographic information, including grade level, preference for physical education, and weekly exercise time, was collected, analyses of these factors were not conducted in this study. The primary focus was on examining self-determination, peer relationships, and P.E. alienation among Chinese and Korean adolescents. There is also a limitation in that the sample size is too small to interpret differences in grade, preference, and exercise time as cultural differences between countries, as such demographic information may vary depending on the city within each country. Future research may consider exploring these additional demographic variables to gain deeper insights into their potential impacts on the key areas of interest.

Conclusion

The findings of this study reveal significant differences in self-determination, peer-relationships, and feelings of alienation among adolescents in South Korea and China. First, Chinese adolescents demonstrated higher levels of self-determination, suggesting that China's physical education programs, which emphasize personal value and growth, should continue to promote autonomy and self-direction among students. Second, South Korean adolescents exhibited stronger peer-relationships, reflecting a cultural emphasis on socialization and interpersonal harmony in their physical education. South Korea should leverage this strength to foster positive peer interactions further. Lastly, feelings of alienation were lower among South Korean male adolescents compared to their female counterparts, highlighting the need for gender-specific approaches in educational programs.

Overall, this research underscores the importance of adapting physical education programs in both countries to reflect their cultural contexts and meet the needs of adolescents. Educators should recognize the strengths and weaknesses of their respective programs

to provide a healthy and inclusive physical education experience for all students. This will serve as foundational data for establishing an educational environment that fosters the physical, mental, and social well-being of youth, as defined by the World Health Organization, who will be the leaders of the future.

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 Institutional Review Board of Jeonbuk National University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

JJ: Project administration, Resources, Validation, Visualization, Writing – review & editing. SY: Data curation, Investigation, Methodology, Writing – original draft. SD: Conceptualization, Formal analysis, Supervision, Visualization, Writing – review & editing.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1417914/full#supplementary-material

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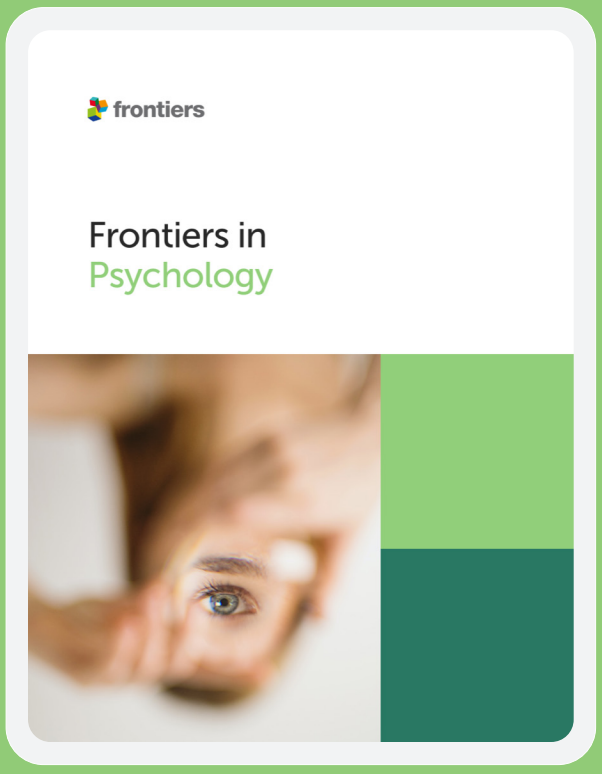

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