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Towards a psychophysiological approach in physical activity, exercise, and sports

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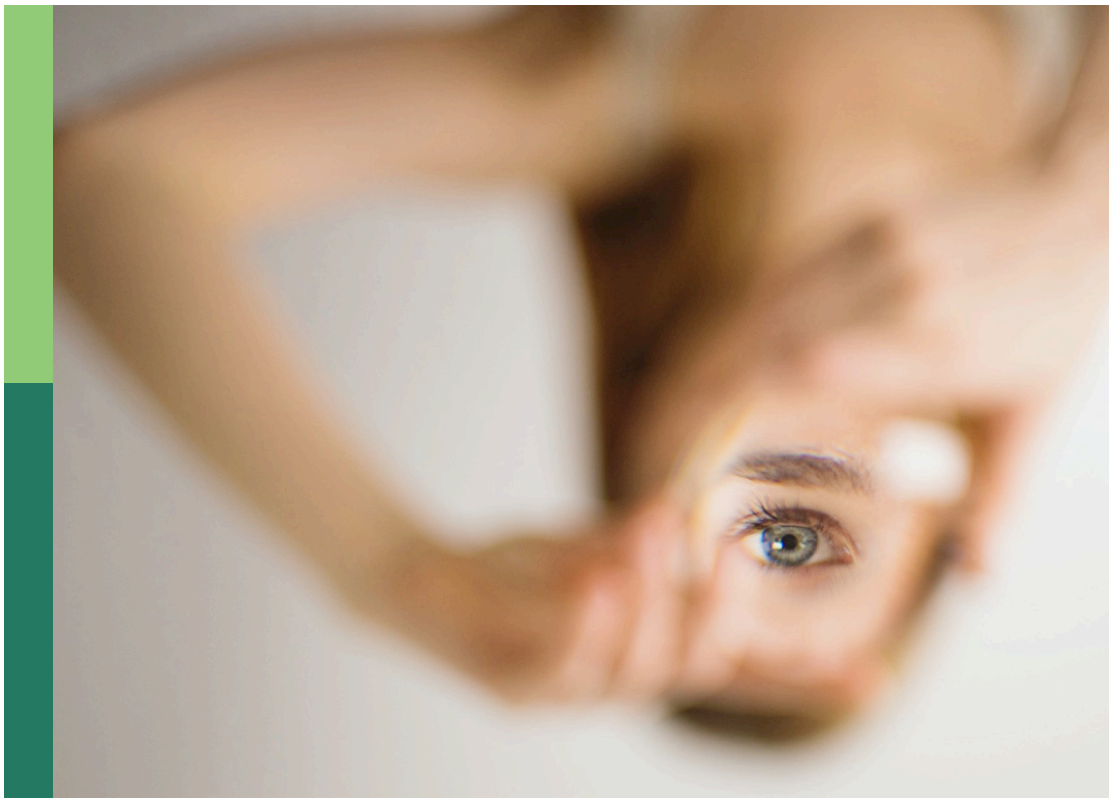

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Towards a psychophysiological approach in physical activity, exercise, and sports

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Editorial: Towards a psychophysiological approach in physical activity, exercise, and sports

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psychophysiological, physical activity, exercise, sport, performance

Editorial on the Research Topic
Towards a psychophysiological approach in physical activity, exercise, and sports

In recent years, a psychophysiological perspective on physical activity, exercise, and sports research has become more popular. Given the strong connections between psychological and physiological aspects, as well as mental fatigue and diseases, psychophysiological and psychological explanations are required. Moreover, human movement and sports performance can also be affected by psychological factors, whereby the regulation of physical capabilities is significantly influenced by the psychophysiological system. It is possible to explain how physical activity and exercise insights are controlled and managed by pacing behavior, decision-making, self-regulation, and effort perception. This Research Topic's goal was to discuss the theoretical and methodological assumptions of the psychophysiological perspective on physical activity, exercise, and sports. In this research area, technical, tactical, physiological, cognitive, and psychological topics were explored in relation to other aspects that affect sports and exercise performance, while the effects of psychological factors on training and performance needs were evaluated. Training interventions assessing acute and chronic adaptations using evaluation and testing procedures make them one of the most important topics in this Research Topic. Research on sports coaching and its relations with mental health and performance were also welcome and considered, intending to provide recent developments within sports sciences research.

A psychophysiological understanding of sports, exercise, and physical activity allows one to construct a bridge between physiological stress and mental wellbeing. In actuality, researchers are still required to provide evidence-based knowledge to coaches and sports scientists to highlight the relationship between training and competition demands, which are related to performance and wellbeing.

In this Research Topic, it is possible to understand that physical exercise can enhance the subjective wellbeing of older adults through sense of meaning in life and self-esteem (Chen et al.). Thus, their perceived competence and sports confidence traits significantly

improved after psychological skills training (Lee et al.). Coach leadership in creating a safe environment provides a much better platform to prepare for a pre-crisis stage (Lee et al.). The most positive factor during preparation for a major competition was the high amount of time focused on technical–tactical training (Paludo et al.). Physiological and physical evaluations at different stages and monitoring and control of training and subjective feedback scales are important for injury prevention (Zhao and Jowett). Youths' mathematical skills and performance are related to fine motricity and special visual motor skills (Flores et al.). Understanding psycho-social factors, such as communication, empathy, cohesion, and competition performance, is essential for successful athletic performance (Lee et al.). Another study explored the influence of social support and proactive personality on the anxiety of college students in the post-pandemic era (Zhao and Jowett). A revised version of the Sport Courage scale was created and presented good reliability and validity, and, based on evidence-based information, it can be used as a measurement tool for Chinese athletes. A review study examined published articles concerning sports leadership over the last 30 years, using bibliometric analysis to explore the intellectual base and structural relationships among relevant research components (Flores et al.). A revised version of the Physical Education Grit Scale is presented in this Research Topic and it can now measure Chinese athletes' physical education grit because of its reliability and validity (Paludo et al.).

This Research Topic showed that to comprehend the intricate interplay between the mind and body during physical activity, exercise, and sports, a psychophysiological approach can be seen as facilitator. This approach acknowledges the interdependence of psychological and physiological elements and their potential influence on both sports performance and general health. Understanding the function of stress and physical demands in physical exercise is crucial to comprehend motor behavior. Psychological factors, such as stress, motivation, and anxiety, can have a detrimental impact on sports performance. The importance of individual variations in physical and athletic performance is another crucial component of the psychophysiological approach. Chronic and acute exerciseactivity responses can be influenced by a variety of factors, including personality traits, motivation, and past experiences. Coaches and trainers may better personalize training plans to each athlete's demands by being aware of these unique distinctions. Finally, the psychophysiological approach offers a thorough framework for comprehending the intricate interactions between the psychological and physiological aspects of physical activity, exercise, and sports. Athletes and coaches may enhance performance and advance general health and wellbeing by approaching training and competition holistically.

Author contributions

PF and DM contributed to conception and design and wrote sections of the manuscript. DP and JT wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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 reviewer LC declared a past collaboration with the authors to the handling editor.

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The relationship between physical exercise and subjective well-being in Chinese older people: The mediating role of the sense of meaning in life and self-esteem

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Purpose: This study explores the relationship between physical exercise and older people's subjective well-being and the mediating role of a sense of meaning in life and self-esteem by using a structural equation modeling (SEM) approach, in order to provide some suggestions for improving older people's subjective well-being.

Methods: In this study, a cross-sectional survey was conducted offline using a simple random method of collection, and the Physical Activity Rating Scale (PARS-3), the Subjective Well-being Scale (SWB), the Meaningfulness of Life Scale (MLQ), and the Self-Esteem Scale (SES) were applied to 419 older adults who participated in physical exercise from Chengdu (Qingyang District, Wuhou District, and Chenghua District), Sichuan Province, China, with the voluntary participation of the subjects. 197 males and 222 females, with a mean age of 72.49 (SD=1.57). The study used SPSS 25.0 and Process 3.5 plug-in for statistical processing of the data, Cronbach's alpha coefficient for intra-variate consistency testing, Harman's one-way test for common method bias testing and multiple covariance diagnosis, and finally regression analysis and Bootstrap sampling test for significance of mediating effects.

Results: Physical exercise was able to have a positive effect on the level of subjective well-being of older adults (β=0.0305; 95% confidence interval (CI): 0.0226, 0.0384; p<0.05), and a mediation analysis of sense of meaning in life and self-esteem revealed that they were able to have independent and chained mediation effects, with four pathways: first, physical exercise directly affected subjective well-being of older adults (β=0.0149; 95% CI: 0.0072, 0.0226; p<0.05; β=0.0149; 95% CI: 0.0072, 0.0226; p<0.05); secondly, sense of meaning in life mediated the relationship between physical exercise and subjective well-being of older adults (β=0.0075; 95% CI: 0.0041, 0.0115; p<0.05); thirdly, self-esteem mediated the relationship between physical exercise and subjective well-being of older adults (β=0.0075; 95% CI: 0.0041,

0.0115; $p<0.05$). (β=0.0061; 95% CI: 0.0034, 0.0094; $p<0.05$); fourth, a chain mediating effect of sense of meaning in life and self-esteem in the relationship between physical exercise and subjective well-being in older adults ($\beta=0.0021$; 95% CI: 0.0010, 0.0035; $p<0.05$).

Conclusion and prospects: As indicated by the results, physical exercise can enhance the subjective well-being of older adults through sense of meaning in life and self-esteem, therefore, in order to be able to enhance the subjective well-being of older adults, enhancing the level of sense of meaning in life and self-esteem of older adults is an effective means.

KEYWORDS

physical exercise, subjective well-being of older people, chain mediation, sense of meaning in life, self-esteem

Introduction

As the number of older people continues to increase, the economic and social development and the system will face serious challenges (Gao, 2022). At the same time, the overall assessment of the quality of life in old age will tend to be subjectively lowered due to the negative realities of retirement, the decline in one's own functioning, reduced care from relatives, and the death of family members (Wu, 2008; Spesivtseva, 2015). As an important indicator of the quality of life, low subjective well-being can lead to depression, anxiety, and other psychological disorders in older people (Diener et al., 1997), which can seriously affect life satisfaction and marital satisfaction. According to Wang (2017)and Jiang et al. (2009), physical exercise is a beneficial physical exercise with a certain intensity, frequency, and duration, which can effectively reduce the risk of cardiovascular disease in the elderly (Li and Gao, 2019). It is able to enhance their mental cognition (Liu et al., 2016), improve memory and executive function (Cai et al., 2021), and boost their quality of life and body confidence (Tokuda and Mori, 2021). Based on the research, it was found that physical exercise that enhances well-being is an essential option for achieving a healthy lifestyle in older adults (Yang et al., 2019). Regular physical exercise can not only significantly improve cognitive function, quality of life, and well-being in older adults (Silverstein and Parker, 2002), but also improve their body's internal environment. However, due to the low awareness and low proportion of physical exercise among the current Chinese elderly population (Gao and Zhang, 2020), it has become an important reason for the deterioration of subjective well-being and quality of life in the process of the paradigm shift of the Chinese population death. The relationship between physical exercise and subjective well-being in university students has been studied, and the mechanisms underlying and mediating the relationship between physical exercise and subjective well-being in older people have been less studied (Zhou and Zhou, 2022). Based on this, this study explores how physical exercise affects subjective well-being in older people and the possible mechanisms underlying the relationship between the two, in order to provide evidence for improving the mental health of older people in the context of increasing aging.

Theoretical basis, research aims, and hypothesis

This study aims to build on existing research to explore the relationship between physical exercise and subjective well-being of older people and its underlying mechanisms. The study shows that Subjective well-being is commonly used to assess personal life satisfaction, the presence or absence of anxiety and depression (Diener, 1994), and other factors such as long-term happiness, pleasant emotions, and life satisfaction. Because many intrinsic elements (such as high quality of life, positive emotions, and so on) are closely related to life experiences, they are more frequently used for individual life evaluations. For older people entering their later years of life, searching for a better life experience is a value and the end of life gives more meaning. Therefore, the question of how to improve subjective well-being in older people has arisen and received much attention. According to Zhai and Wang (2018), social support, the external environment, and mental health all predict subjective well-being in older people. Meanwhile Zhan and Zhao (2018), proposed that older people's subjective well-being is closely related to the community environment, the number of community services, and community capital. At present, there is a wealth of research on the relationship between physical exercise and subjective well-being, but most of the studies focus on the relationship between physical exercise and subjective well-being of university students or middle-aged people, while few studies have explored the interrelationship between physical exercise and subjective well-being of older people and their underlying mechanisms. Therefore, it is the starting point of this study to enrich the theoretical system of the relationship between physical exercise and subjective well-being of the elderly, and then to provide evidence to enhance the subjective well-being of the

elderly by discovering other factors that may exist between the two.

The effect of physical exercise on subjective well-being of older people

Physical exercise is defined as a conscious and purposeful social activity undertaken by individuals or groups to achieve physical and mental pleasure, enhance social interaction, and experience cultural life (Lu, 2011), Quality of life, life satisfaction, and physical fitness have all been shown in studies to be important indicators of subjective well-being (Xu and Xia, 2014). Simultaneously, Zheng et al. (2016) suggest that physical exercise can promote physical and mental health, strengthen self-confidence, and ultimately achieve a sense of meaning in life. In response to this conclusion, Luo et al. (2008) further concluded that physical exercise for the elderly should be done over a long period of time in order to sustain the positive effects on quality of life and subjective well-being. In addition, Stathi et al. (2010) suggest that physical exercise, with the exception of material well-being, can influence all aspects of subjective well-being in older people and promote psychological well-being by maintaining a busy life course, subjectively creating an active lifestyle, maintaining a good mental state, and a better attitude toward life. At the same time, McAuley and Rudolph (1995) stated that physical exercise is closely related to subjective well-being, it is unaffected by age or gender, but only by the physical condition of the subjects and the subjective well-being measurement methods. Wang et al. (2018) believe that physical exercise can improve social and economic status and behavior, thereby improving subjective well-being. There are also studies on physical exercise intervention for elderly medical patients. Following the experiment, it was discovered that patients' quality of life and physical health had significantly improved, implying that patients' subjective well-being had improved during treatment (Oldervoll et al., 2004). Therefore, based on the above analysis, this study proposes the hypothesis H1: Physical exercise positively predicts subjective well-being in older adults.

The mediating role of a sense of meaning in life

Research on the relationship between physical exercise and subjective well-being in older adults have shown sophisticated mediating mechanisms. Physical exercise may affect elder's subjective well-being by enhancing their sense of meaning in life, Normally (Ding et al., 2016). A subjective psychological assessment of a person's future life objectives, directions, missions, and meanings is done through an independent judgment of the worth and significance of their current existence (Steger et al., 2008). It has a direct impact on life satisfaction, physical and mental health, and filial piety (Xie et al., 2012; Xu et al., 2020; Li et al., 2021). It has become one of the hottest scientific subjects in recent years. The final stage of life, old age, has a special significance. Exploring the connection between the meaning of life and how physical exercise affects the subjective well-being of the elderly is particularly crucial, because when people move from an active existence to a pleasant old age, they must modify their expectations for the future. According to study, a person's subjective well-being as well as their physical and mental health may be enhanced by having a better sense of meaning in life (Ye et al., 2019). A higher sense of meaning in life can not only improve physical and mental health but also life satisfaction, experience, and the prevalence of anxiety and depression, according to other linked studies (Nell, 2014; Bamonti et al., 2016). Simultaneously, some researchers argue that the motivation (meaning pursuit) and cognition (meaning experience) contained in sense of meaning life cannot all predict subjective well-being. Only one aspect of quality of life clearly demonstrates that it is more important in the process of improving well-being and reducing depression and anxiety symptoms. This is because it is unclear how much each aspect of the sense of meaning in life affects the subjective well-being of the elderly, and it is necessary to figure out how a sense of meaning in life can act as an intermediary variable between the former and the latter (Steger et al., 2009; Hallford et al., 2018). The current study's findings are inconclusive as to whether the meaningful life pursuit component affects well-being. Given the uncertainty regarding the extent to which the dimensions of sense of meaning in life affect subjective well-being in older adults, as well as the need to understand how sense of meaning in life as a mediating variable plays a role between the two before and after, this study proposes hypothesis H2: based on the preceding research, sense of meaning in life may play a mediating role in the relationship between physical exercise and subjective well-being in older adults.

The mediating role of self-esteem

Self-esteem is an important outcome variable for physical exercise and may be another important internal factor (Zhu and Li, 2022), in the relationship between physical exercise and subjective well-being in older adults (Duman et al., 2016). It is a critical outcome variable in physical exercise. Individuals or organizations, according to the Social Information Processing Theory (SIPT) hypothesis, obtain relevant information from the immediate environment in which they participate in physical exercise, and interpret expectations about the occurrence and outcomes of physical exercise events, which leads to changes in self-worth judgments of individuals or members within the organization, and further influences levels of self-esteem. Physical exercise, according to research, can help female athletes improve positive psychosocial factors such as self-confidence, self-esteem, and decisiveness (Ferguson et al., 2019). Physical exercise, on the other hand, as an organized activity, is likely to have an impact on the self-esteem levels of older people. In addition, self-esteem is a

strong predictor of subjective well-being and an important factor in the psychological well-being of older people, with high self-esteem implying positive attitudes toward values (Cheng and Furnham, 2003). This suggests that in older adults, self-esteem is a likely mediator of physical exercise as a predictor of subjective well-being. Current research on the effects of physical exercise on the subjective well-being of older people, however, has primarily focused on external variables such as place attachment, social interaction, and physical health status. Few studies have examined the relationship between physical exercise and subjective well-being in older adults, with psychological mechanisms such as self-esteem serving as moderators. As a result, the following hypothesis H3 is proposed in this study: Self-esteem may play a mediating role in the relationship between physical exercise and subjective well-being in older adults.

The chain mediating role of sense of meaning in life and self-esteem

Furthermore, the sense of meaning in life and self-esteem are important factors influencing quality of life and physical and mental health, they are both conditioned by physical exercise (Zhang et al., 2021), which implies that a sense of meaning in life and self-esteem may play a chain mediating role in the effect of physical exercise level on subjective well-being of older adults. To begin, Wong (2010) propose that the meaning of life influences an individual's internal psychological perceptions, such as reducing the unpleasantness of life processes and mitigating hardships by increasing levels of self-esteem. Secondly, research indicates that purpose, correctness, self-efficacy, and self-worth satisfaction are the four important sources for the formation of a sense of meaning in life (Baumeister, 1991), with self-efficacy and self-worth being subordinate to self-esteem. Given the similarity of the two connotation factors, it is reasonable to conclude that a sense of meaning life is an important factor influencing individual self-esteem. The sense of meaning in life positively predicts self-esteem, that is, the higher the sense of meaning in life, the higher the level of self-esteem reflected by individuals (Cao et al., 2019). Existing research confirms that physical exercise can affect older people's subjective well-being both directly and indirectly *via* the sense of meaning in life or self-esteem, but no literature exists on whether the sense of meaning in life and self-esteem play a chain mediating role in the relationship between physical exercise and older people's subjective well-being. Given the importance of improving older adults' psychological health and promoting the growth of well-being, as well as the importance of investigating physical exercise to promote subjective well-being among older adults, this study proposes hypothesis H4: A sense of meaning in life and self-esteem may play a chain mediating effect in the relationship between physical exercise and subjective well-being of older adults.

In summary, following the literature review and theoretical confirmation, this study suggests that a sense of meaning in life and self-esteem may be mediating variables between physical exercise and subjective well-being in older people (Figure 1).

Research methodology

Study subjects

An offline survey was conducted between 11 September 2021 and 19 December 2021 through offline face-to-face communication using a simple random sampling method among 450 older people aged 60 years and above from Chengdu (Qingyang District, Wuhou District, and Chenghua District), the capital of Sichuan Province, China, who had experienced physical exercise in the past month. The questionnaires were made clear to the subjects before the survey and the corresponding terms and conditions, and were completed independently or guided anonymously with the consent of the subjects and their families, and dictated by the investigator to ensure that the subjects could fully understand the meaning of each question item. After completing the overall survey, the data were checked and 31 questionnaires that were not completed in a standard way or missing answers were excluded, resulting in a total of 419 valid questionnaires with an effective rate of 93.11%. One hundred ninety-seven males and 222 females were included in the sample, with a mean age of 72.49 (SD = 1.57). The Ethics Review Committee (approval no. CTYLL2022001) of Chengdu Sports Institute, China, approved and supervised the entire content of this study. See Table 1 for basic information about the older people who participated in the survey.

Measuring tools

Physical exercise rating scale

This study used the Physical Activity Rating Scale (PARS-3) revised by Liang (1994), which measures physical exercise rating from three perspectives: frequency, time, and intensity. Physical Activity Rating = Frequency x Time x Intensity, and all three dimensions are scored on a 5-point Likert scale. The higher the score, the more intense, more frequent, and longer the exercise, and conversely, the less intense, less frequent, and shorter the exercise. The physical exercise scale scores range from 0 to 100, with scores $\leq$19 being the low-level exercise group, scores between 20 and 42 being the medium-level exercise group, and scores $\geq$43 being the high-level exercise group. According to statistics, the physical exercise level of all older people was 33.69 (SD = 31.39). The overall Cronbach's alpha coefficient for the PARS-3 was 0.836 (overall values range from 0 to 1; a coefficient of $<$0.6 indicates that the scale has low internal consistency; a coefficient of 0.7–0.8 indicates that the scale has good reliability; a coefficient of 0.8–0.8 indicates that the scale has good reliability; and a coefficient between 0.8 and 0.9 indicates very good reliability).

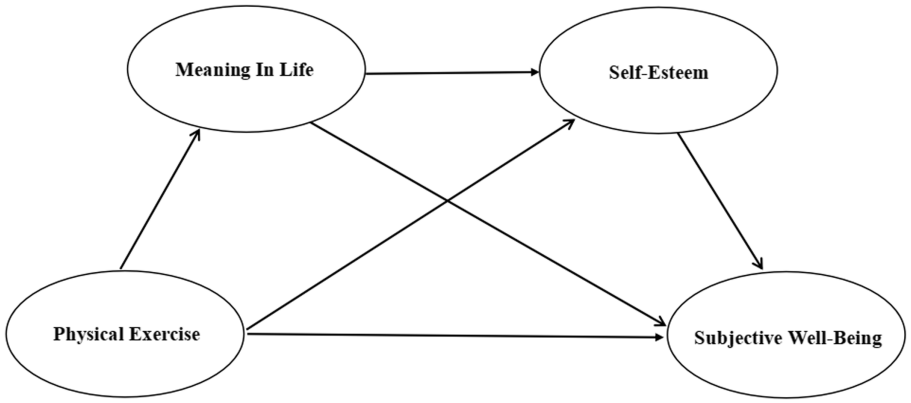

FIGURE 1
Research hypothesis model.

TABLE 1 Subjects' basic information characteristics (N=419).

Category	Frequency	Percent
Gender		
Male	197	47.1
Female	222	52.9
District		
Qingyang district	91	21.71
Wuhou district	186	44.39
Chenghua district	142	33.89
Education level		
junior college and above	97	23.15
middle school	274	65.39
Other	48	11.46

Subjective well-being questionnaire

The Subjective Well-Being Scale (SWB) was developed by Campbell (1976), The SWB consists of eight general affective index items (weighted at 1.0) and one life satisfaction item (weighted at 1.1) on a 7-point Likert scale, with total subjective well-being scores ranging from 2.1 (least happy) to 14.7 (happiest), with higher total scores indicating higher levels of subjective well-being and vice versa. Validation of the measurement model resulted in a fit of $X^2/df = 0.923$, Goodness-of-Fit Index (GFI) = 0.988, Comparative Fit Index (CFI) = 1, Tucker-Lewis Index (TLI) = 1, Root Mean Square Error of Approximation (RMSEA) = 0.000, and Standardized Root Mean Square Residual (SRMR) = 0.014 (Wei, 2008). The overall Cronbach's alpha coefficient for the SWB was 0.929 (overall values range from 0 to 1; a coefficient of <0.6 indicates that the scale has low internal consistency; a coefficient of 0.7–0.8 indicates that the scale has good reliability; a coefficient of 0.8–0.8 indicates that the scale has good reliability; and a coefficient between 0.8 and 0.9 indicates very good reliability).

The sense of meaning in life scale

The Meaningful Life Scale (MLQ) was developed by Steger and revised by Wang and Dai (2008). The MLQ contains two dimensions, the presence of meaning (MLQ-P) and the search of meaning (MLQ-S), with a total of 10 questions. The items ranged from "1 = not at all agree" to "7 = completely agree," with a higher total score indicating a stronger sense of meaning in life, and vice versa. $X^2/df = 0.922$, GFI = 0.985, CFI = 1.001, TLI = 1.001, RMSEA = 0.000, and SRMR = 0.015.0.015, indicating good scale construct validity. The overall Cronbach's alpha coefficient for the MLQ was 0.934 (overall values range from 0 to 1; a coefficient of <0.6 indicates that the scale has low internal consistency; a coefficient of 0.7–0.8 indicates that the scale has good reliability; a coefficient of 0.8–0.8 indicates that the scale has good reliability; and a coefficient between 0.8 and 0.9 indicates very good reliability).

The self-esteem scale

In this study, the Rosenberg Self-Esteem Scale (SES) was used to measure the self-esteem of older people (Tian, 2006). The 10-item scale consists of two sections: self-affirmation, such as "I think I have a lot of good qualities," and self-denial, such as "I often think I am useless" The scale is scored on a 4-point Likert scale, with questions 3, 5, 8, 9, and 10 being scored inversely, with each question ranging from "1 = very unlikely" to "4 = very likely," with higher scores indicating higher levels of self-esteem. $X^2/df = 1.303$, GFI = 0.979, CFI = 0.995, TLI = 0.994, RMSEA = 0.027, SRMR = 0.021. This indicates good construct validity of the SES. The Cronbach's alpha coefficients for the self-affirmation and self-denial subscales were 0.852 and 0.850, respectively (overall values range from 0–1; a coefficient of < 0.6 indicates that the scale has low internal consistency; a coefficient of 0.7–0.8 indicates that the scale has good reliability; a coefficient of 0.8–0.8 indicates that the scale has good reliability; and a coefficient between 0.8 and 0.9 indicates very good reliability).

Data analysis

SPSS 25.0, Bootstrap method, and SPSS macro program Process 3.5 plug-in (Model 6) were used for questionnaire data entry, statistical analysis, and chain mediating effect testing in the following order.

Firstly, the internal consistency of each variable was tested for reliability using Cronbach's alpha coefficient.

Secondly, the Harman singleton test was used to test for the presence of common method bias in four variables: physical exercise, subjective well-being of older people, sense of meaning in life, and self-esteem.

Again, the mean, standard deviation and correlation coefficient of each variable were calculated using SPSS 25.0.

Again, covariance diagnosis is performed for possible multicollinearity.

Finally, regression analysis and the macro program Process 3.5 were used to conduct independent and chain mediating effect analysis of sense of meaning in life and self-esteem.

Study results

Common method deviation test

As the questionnaire was completed in an anonymous paper format, which is highly subjective, for possible cases of common method bias, this study conducted an unrotated exploratory factor analysis of the 31 variable entries in this study using the Harman one-way test. The results showed that four of the factors had eigenvalues greater than one and the first factor explained 36.02% of the variance, which was below the 40% threshold. So it can be inferred that there was no significant common method bias for the variables involved in this study.

Correlation analysis of physical exercise, subjective well-being, sense of meaning in life, and self-esteem in older people

Physical exercise is significantly and positively related to subjective well-being, sense of meaning in life, and self-esteem, according to the findings in Table 2; subjective well-being is positively related to sense of meaning in life and self-esteem; and sense of meaning in life is positively related to self-esteem. This demonstrates that there is a significant positive correlation between the aforementioned variables, providing a foundation for future research to determine whether there is a chain mediating effect between the sense of meaning in life and self-esteem in the relationship between physical exercise and subjective well-being in the elderly.

Multicollinearity test

To avoid problems with multicollinearity caused by significant correlations between all variables, which could result in unstable final results. The decision was made in this study to diagnose covariance using subjective well-being of older adults as the dependent variable and physical exercise, sense of meaning in life, and self-esteem as the independent variables, and to standardize each predictor variable. The results showed that each predictor variable's tolerance value (0.846, 0.825, and 0.793) was greater than 0.1 and the VIF value (1.182, 1.212, 1, and 0.261) was less than 5. It can be concluded that the data did not have any multicollinearity issues and that it was suitable for further chain mediation effect testing.

Analysis of the mediating effects of a sense of meaning in life and self-esteem

Using physical exercise as the independent variable, sense of meaning in life and self-esteem as mediating variables, and subjective well-being of older adults as the dependent variable, Hayes (2013) Bootstrap mediated effects analysis was conducted using Model 6 in the SPSS macro program Process 3.5 plug-in developed by Hayes. In this case, the replicate sample was 5,000 and the default confidence interval was 95%.

As the results in Table 3 and Figure 2 show, first, physical exercise not only directly and significantly and positively predicted subjective well-being ($\beta = 0.149$, $p < 0.001$), but also significantly and positively predicted sense of meaning in life ($\beta = 0.119$, $p < 0.001$) and self-esteem ($\beta = 0.056$, $p < 0.001$); second, sense of meaning in life significantly and positively predicted self-esteem ($\beta = 0.162$, $p < 0.001$) and subjective well-being ($\beta = 0.063$, $p < 0.001$); and third, self-esteem significantly predicted subjective well-being ($\beta = 0.108$, $p < 0.001$). This suggests that a sense of

TABLE 2 Correlation analysis of physical exercise, subjective well-being, sense of meaning in life and self-esteem in older people (N=419).

Variables	*M*	SD	1	2	3	4
1 Physical exercise	33.69	31.43	1			
2 Subjective well-being of older people	37.20	12.62	0.295**	1		
3 Sense of meaning in life	23.44	6.75	0.351**	0.381**	1	
4 Self-esteem	8.37	2.75	0.348**	0.440**	0.434**	1

**$p < 0.01$.

TABLE 3 Chain mediated model regression analysis of physical exercise, sense of meaning in life and self-esteem on subjective well-being of older people.

Regression equation		Overall fit index			Regression coefficient				
Resulting variables	**Predictive variables**	***R***	***R*²**	***F***	***β***	**SE**	***t***	**LLCI**	**ULCI**
sense of meaning in life	Physical exercise	0.295	0.087	39.824***	0.295	0.047	6.311***	0.203	0.387
Self-esteem	Physical exercise	0.455	0.207	54.387***	0.262	0.046	5.727***	0.172	0.352
	sense of meaning in life				0.303	0.046	6.637***	0.213	0.393
Subjective well-being	Physical exercise	0.549	0.301	59.688***	0.170	0.045	3.814***	0.082	0.258
	sense of meaning in life				0.289	0.045	6.404***	0.200	0.378
	Self-esteem				0.265	0.046	5.740***	0.174	0.355
Subjective well-being	Physical exercise	0.348	0.121	57.609***	0.348	0.046	7.590***	0.258	0.439

***$p < 0.001$.

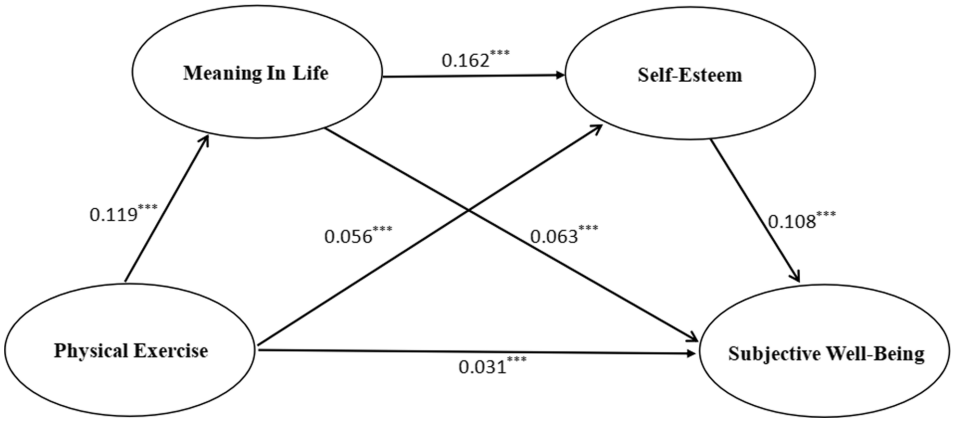

FIGURE 2
Diagram of the chain mediator model of a sense of meaning in life and self-esteem. ***p<0.001.

meaning in life and self-esteem play a full chain mediating effect between physical exercise and subjective well-being.

As the results in Table 3 show, firstly, the mediation analysis yielded a total mediating effect of 0.1783, accounting for 51.18% of the total effect, and the 95% confidence interval (0.1177–0.2486) did not contain 0, indicating that the model with a chain of mediating variables of sense of life meaning and self-esteem held true and had some reliability. Secondly, by adding sense of life meaning and self-esteem to the relationship between physical exercise and subjective well-being, there were four pathways for the effect of physical exercise on subjective well-being. The direct effect of path 1 (physical exercise → subjective well-being) was 0.1701, with an effect ratio of 48.82%; the mediating effect of path 2 (physical exercise → Sense of meaning in life → self-esteem → subjective well-being) was 0.0237, with an effect ratio of 6.80%; the mediated effect of path 3 (physical exercise → Sense of meaning in life → subjective well-being) was 0.0854, with an effect of 24.51%; and the mediated effect for path 4 (physical exercise → self-esteem → subjective well-being) was 0.0692, with an effect ratio of 19.86%. The 95% confidence intervals of the above four pathways do not contain zero values, indicating that in the relationship between physical exercise and subjective well-being of the elderly, physical exercise, sense of meaning in life, and self-esteem can each independently influence subjective well-being, and sense of meaning in life and self-esteem can also jointly play a chain mediating effect, providing valid evidence for the above research hypothesis (Table 4).

Discussion

The effect of physical exercise on subjective well-being of older people

Data analysis revealed that physical exercise predicted subjective well-being in older adults. This finding supports the study's hypothesis and is consistent with the findings of Zheng research (Zheng, 2019). As a result, hypothesis H1 holds true, implying that the level of physical exercise is related to the level of subjective well-being of older adults, i.e., the higher the level of physical exercise rating, the higher the subjective well-being of older adults. Lower subjective well-being has been identified as one of the important factors contributing to high suicide rates, loneliness, and depression in older people (Wu et al., 2014; Bartlett

TABLE 4 Chain mediation effect test between sense of meaning in life, self-esteem in physical exercise and subjective well-being.

Intermediary effect pathway	Standardized indirect effect values	Boot SE	95% confidence interval	Relative effects
Total effect	0.3484	0.0459	[0.2582–0.4386]	100%
Direct effects	0.1701	0.0446	[0.0824–0.2578]	48.82%
Physical exercise → Sense of meaning in life → Self-esteem → Subjective well-being	0.0237	0.0072	[0.0116–0.0396]	6.80%
Physical exercise → Sense of meaning in life → Subjective well-being	0.0854	0.0209	[0.0474–0.1331]	24.51%
Physical exercise → Self-esteem → Subjective well-being	0.0692	0.0176	[0.0374–0.1071]	19.86%
Total intermediary effect	0.1783	0.0339	[0.1177–0.2486]	51.18%

and Arpin, 2019; Soósová et al., 2021). Physical exercise, as an external aid known to effectively counteract negative human emotions, will help to reduce the risk of suicide and depression, as well as loneliness (Sun and Stuart, 2002; Chen et al., 2010; Rogers et al., 2019). This can increase one's subjective well-being. At the same time, a study also found that participating in physical exercise at a certain frequency and intensity helps older people strengthen their lower limb function while also improving their mental outlook and subjective well-being (Withall et al., 2014). The study also found that engaging in physical exercise at a certain frequency and intensity improved lower limb mobility as well as the mental outlook and subjective well-being of older people. Based on the preceding discussion, the hypothesis that physical exercise has a positive effect on the subjective well-being of older people is strengthened.

The mediating role of a sense of meaning in life between physical exercise and subjective well-being of older people

The finding that a sense of meaning in life mediates the positive impact of physical exercise on subjective well-being in older adults supports Hypothesis 2. On the one hand, the study found that older adults who did not engage in physical exercise were more likely to experience anxiety, depression, helplessness, and other negative mental states that affect healthy physical and mental development, which lead individuals to lower their self-evaluation and generate a low sense of meaning in life through low self-evaluation, which ultimately inhibits the enhancement of subjective well-being. The lack of subjective well-being is exacerbated further by the increasing frequency of death cues in everyday life as a result of illness and declining body functions, particularly in old age (Binder and Buenstorf, 2018). On the other hand, this hypothesis is consistent with the self-worth theory, which states that in older people, a sense of meaning in life is a motivation to pursue and create value and meaning later in life, and that it is a powerful motivator to continue seeking newness and happiness in life. Older people who have a strong sense of meaning in life are more likely to envision a better future and take positive steps toward it, resulting in significant changes in their emotional feelings and lifestyles (Ju et al., 2013). This results in significant changes in emotional feelings and lifestyle choices, which contribute to an increase in subjective well-being. Conversely, older people who lack a sense of meaning in life and confidence in their future are more likely to exhibit negative feelings toward various things, which in turn impairs their subjective well-being. The findings of this study clarify the role of sense of meaning in life in enhancing subjective well-being and provide evidence of how physical exercise affects older people's subjective well-being.

The mediating role of self-esteem in the relationship between physical exercise and subjective well-being of older adults

Self-esteem is widely used in various sports psychology studies that measure post-exercise psychological representational characteristics as an important indicator of an individual's psychological well-being (García et al., 2012). It has been proposed that long-term, consistent participation in physical exercise can address both low self-esteem and potential disease risk. A similar study in 246 older adults in China found a significant difference in self-esteem levels between those who did not exercise and those who did exercise, and that physical exercise not only directly but also indirectly influences the self-esteem levels of older adults (Yin et al., 2008), It is a significant factor influencing older people's self-esteem. Furthermore, self-esteem is regarded as one of the most reliable predictors of subjective well-being (Diener and Diener, 1995; Diener, 2000). A review of previous research indicates that self-esteem is an important moderator in the relationship between physical exercise and subjective well-being. Square dancing, for example, as a form of self-organized physical exercise for Chinese older people, has changed their lifestyle and effectively improved their quality of life and sense of meaning in life (Shu, 2017). In this regard, Wu et al. (2019) conducted a study on the elderly population in square dance organizations. The study found that self-esteem could play a separate mediating role between physical exercise and subjective well-being, as well as a chain mediating role with organizational identity, which is consistent with the findings of this study. Therefore, the hypothesis H3 that

self-esteem plays a mediating role between physical exercise and subjective well-being of older adults holds true.

The chain mediating role of sense of meaning in life and self-esteem in the relationship between physical exercise and subjective well-being of older adults

Existing research suggests that having a sense of meaning in life can boost one's self-esteem. Individual frustration, as Liu et al. (2020) pointed out in her study, is strongly influenced by a lack of a sense of meaning in life. Goal process theory suggests that value-expected goals guide changes in individuals' value actions and perceptions, and when the results of actions do not match the expected goals, individuals develop strong negative emotions and engage in profound self-denial, resulting in individuals feeling more negative emotions and a decrease in self-esteem (Sang et al., 2019). This leads to a decrease in self-esteem. The elderly who have a higher sense of meaning in life can look forward to their future and deal positively and optimistically with all types of adverse events in their lives, which leads to good emotional feelings at all times, and when they face their lives in a positive state, their self-esteem will increase. As a result of the preceding research, this study investigated the mediating role of sense of meaning in life and self-esteem between physical exercise and subjective well-being in older adults and confirmed the chain mediating role of sense of meaning in life and self-esteem between physical exercise and subjective well-being in older adults, with hypothesis H4 being valid. Takkinen et al. (2001) discovered through long-term follow-up that older adults who regularly participated in physical exercise had a higher sense of meaning in life and that a good sense of meaning in life promotes higher self-esteem (Cao et al., 2019) and may further influence the perceived well-being of older adults including subjective well-being, optimistic experiences, and self-efficacy.

Implications

Population aging is a significant social and public issue in China (Fang, 2021), Individuals, organizations, and nations will all face psychological and practical consequences. As the elderly population grows, it is important to pay attention to their physical and mental health. Physical exercise has long been recognized as an effective means of promoting individuals' positive mental health (Wurm et al., 2014). This study reveals the impact of physical exercise on the subjective well-being of older people in China, as well as the mediating role of a sense of meaning in life and self-esteem, providing a foundation for positive psychological interventions for older people in order to effectively promote their psychological well-being.

This study further affirms the value of physical exercise on the basis of relevant research, and provides important support for enhancing the subjective well-being of older people through participation in physical exercise. In addition, we should encourage as many older people as possible to take part in regular and regular physical exercise.

Some scholars believe that good health problems, psychosocial competence, and social support can be effective in enhancing older people's sense of meaning in life (Golovchanova et al., 2021). Other researchers have identified successful events experienced in life as an important factor in enhancing the level of self-esteem in older people (Rosi et al., 2019). Effectively supporting the existence of a chain mediating role of a sense of meaning in life and self-esteem in the relationship between physical exercise and subjective well-being in older adults, it opens up new pathways for interventions in the development of subjective well-being in older adults. Therefore, in the future life process, the subjective well-being of older people can be systematically enhanced through targeted participation in physical exercise and enhancing the level of sense of meaning in life and self-esteem.

Conclusion

Physical exercise was found to be a significant predictor of subjective well-being in older people.

In older people, a sense of meaning in life and self-esteem levels can be mediated either individually or in a chain between physical exercise and subjective well-being. That is, the higher the level of physical exercise, the higher the sense of meaning in life and self-esteem of older people, which ultimately leads to an increase in subjective well-being. As a result, increasing older people's sense of meaning in life and self-esteem levels will contribute to an increase in subjective well-being.

Limitations and future research directions

This study provides a theoretical and practical reference for future research by explaining the complex psychological relationship between physical exercise participation, sense of meaning in life, self-esteem, and subjective well-being among Chinese older people. However, there are still some limitations in this study: (1) Because this is a cross-sectional study with many unexplored and uninvolved influencing factors, conducting a longitudinal study is an important task for consolidating this research in the next stage. (2) The independent and chain mediating role of sense of meaning in life and self-esteem between physical exercise and subjective well-being in the elderly is revealed in this study. However, due to China's vast territory, there may be some variations in the exercise habits and methods of the elderly of different genders in different locations. As a result, in the next step, this study will consider moderating variables such as city, age, gender, income,

marital status, and education level. (3) This study examined the relationship between the intensity, duration, and frequency of physical exercise and subjective well-being of older people. However, as the type of exercise program may affect the findings, the next study will consider the effects of exercise intensity, duration, and frequency of participation in different types of programs on the subjective well-being of older people based on the distinction between objective evaluation and subjective perception, as well as the mediating effects of related intrinsic 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

The studies involving human participants were reviewed and approved by Chengdu Sport University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RC was responsible for analyzing the experimental data and writing and revising in English. G-DH and P-CW were responsible for collecting, collating, and analyzing the experimental data. Y-FL was responsible for conceptualizing and checking and revising the article. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1029587/full#supplementary-material

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Coach leadership in a crisis context: Investigating effective coach behaviors during the COVID-19 pandemic with a process view

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Introduction: Drawing from the crisis leadership conceptualization, this study aims to investigate coaches' opinion patterns on effective leadership behaviors during the COVID-19 pandemic. The study used a process view to explore how coaches as leaders act in pre, during, and post-crisis phases.

Method: Thirty-two fulltime professional coaches (28 males and 4 females) from individual and team sports who experienced the entire COVID-19 pandemic from January 2020 to July 2021 in the United Kingdom were invited to express their perceptions of effective leadership behaviors. The study used Q methodology to analyze coaches' perceptions and experiences.

Result: The study revealed that the most effective coach leadership behaviors occurred during-crisis phase, which has the most positive ratings (n = 48) compared to the pre-and post-crisis phases (n = 18). The study's main findings highlighted different phases of the COVID-19 pandemic demand various effective countermeasures from coaches. These practical and successful experiences were summarized as: division of labor, athlete-centered, team-driven, consulting, safe environment, and online coaching.

Discussion: The findings of this study further highlight (1) the importance of coach leadership in creating a safe environment as it provides a much better platform to prepare for a pre-crisis stage, (2) that coaches should employ more positive than negative behaviors while interacting with team members more frequently especially during the crisis period, reducing athletes' negative feelings such as anxiety and worry, and (3) that the online training-related activities and interactions during the crisis time can be expanded to noncrisis times, as a crisis event can have positive implications for the future if handled properly.

KEYWORDS

online training, team psychological safety, Q-method, crisis leadership, coaching behavior, leadership context

Introduction

Leadership behaviors are determined and shaped by context (Vella et al., 2010; Oc, 2018; Stoker et al., 2019), the context "has frequently been shown to influence the observed range or base rates of the leadership variables of interest, to change the nature of examined relationships and to threaten the generalizability of findings" (Oc, 2018, p. 230). The recent COVID-19 pandemic has drawn attention to examining leadership in the context of crisis (Wu et al., 2021; Garretsen et al., 2022). The COVID-19 pandemic has impacted individuals and organizations globally and has affected the sports industry. Various sports practitioners had to change their routines and lifestyles significantly (Taku and Arai, 2020; Bratland-Sanda et al., 2021). Moreover, major international sports events (e.g., 2020 Olympics games) had to be ceased and postponed (BBC Sport, 2020). The amount of research during the COVID-19 pandemic in sports covered sports populations such as athletes (Roberts et al., 2020), people with disabilities (Kamyuka et al., 2020), and personal trainers (Bratland-Sanda et al., 2020). However, coaches, as critical sports participants, received less research attention.

In sports, coaches as leaders play an important leading role within teams, squads, groups of athletes, and other practitioners (Arthur and Bastardoz, 2020; Cotterill and Fransen, 2021; López de Subijana et al., 2021), as they take responsibility for creating a safe social environment and conducting effective coaching activities (Fransen et al., 2020; Gosai et al., 2021). The pandemic has brought more challenges for coach leadership. The various quarantine and lockdown policies had subjected coaches and other sports practitioners to restrictions. Such restrictions directly affected athletes' training time, with athletes' average weekly training time decreased by 27.6% after the start of lockdown (Zinner et al., 2020). Also, athletes cannot return to the field effectively due to training at home, where the injury rate in the first game has risen sharply (Seshadri et al., 2021). At the same time, home confinement pushed coaches to seek new training routines to transform difficulties into opportunities, such as online training (Moreno-Tenas et al., 2021). Thus, it is meaningful to investigate how coach leaders overcame these difficulties and gained an understanding and experience from having to manage a global crisis.

The present study builds on recent research that aimed to explore crisis leadership as a process (Bundy et al., 2017; Wu et al., 2021) with the aim to investigate coaches' leadership behaviors around the time of the COVID-19 pandemic. Accordingly, taking a process-oriented view, we examined coach leadership in multiple primary phases: pre, during and post-crisis phases. Viewing a crisis as a process addresses a novel question that can help coaches assign appropriate measures at specific times rather than utilizing particular characteristics of the coach throughout the crisis event (Wu et al., 2021). Such process view of crisis leadership also aligned with sports scholars' view of the COVID-19 pandemic (Samuel et al., 2020). Samuel et al. (2020) conceptualized the COVID-19 pandemic as a "change event" with four distinct stages–"pre-COVID-19 pandemic stage," COVID-19 pandemic stage A, B (during the crisis time), and C (return to normal time). The UK's lockdown policies provided ideal time period divisions. The UK had a relative sufficient pre-crisis stage since it was not among the first countries with an outbreak for a while. According to the official information provided by the UK government, the phases of this pandemic were as follows: the pre-COVID-19 (before first national-lockdown, March 2020), During COVID-19, and post-COVID-19 (after July 2021) (GOV.UK, 2021).

Wu et al. (2021) have conceptualized crisis events and crisis leadership, and the discussion that follows elaborates on these conceptualizations while applying them to coach leadership. The crisis event has been conceptualized on the basis of three key characteristics: (1) "*Unexpectedness,*" crisis event is different from normal events that occur frequently, a crisis is a situation that would not provide too much preparation time to organizational leaders. (2) "*Salience,*" such salience mainly reflects the perceived significance of the impact and urgency of the response. With these two characteristics in mind, coaches would face and experience a crisis with little time for preparation while subjectively evaluating objective crisis events. Meanwhile, time is paramount in this evaluation process. It is expected that different coach leadership behaviors result in various detections and appraisals of crisis events (c.f., Wu et al., 2021) and psychological factors, directly and indirectly, influence the coaches' decisions, such as personal traits and leadership style (Kajtna and Barić, 2009). The last characteristics of crisis event is (3) "*Disruption,*" while crisis is a type of disruption, it has great potential for an organization (e.g., Bundy et al., 2017). In sports, many coaches and athletes faced big challenges and changes of lifestyle and lack of self-fulfillment during the pandemic (Taku and Arai, 2020). It has been reported that among others, athletes' sleep pattern, training intensity, and eating habits changed significantly during the lockdown period (Pillay et al., 2020). Also, athletes perceived more stress compared to normal time (di Fronso et al., 2022). However, it is worth noting that crises can also be transformed into opportunities if handled properly (James et al., 2011). For example, rookie and injured athletes had more time to prepare and recover because of the COVID-19 pandemic crisis (Schinke et al., 2020; Taku and Arai, 2020).

Regarding the definition of coach crisis leadership, we referred to the general definition of crisis leadership as was put forward by Wu et al. (2021, p. 3) whereby crisis leadership is defined "as a process in which leaders act to prepare for the occurrence of unexpected crises, deal with the salient implications of crises, and grow from the disruptive experience of crises." This definition was applied to crisis leadership as manifested by coaches over a period that included three states: preparation, confrontation, and growth. During this dynamic process, coaches first need to react and prepare for a crisis event; then, coaches identify appropriate behaviors and/or carry

out specific measures during the crisis period; lastly, coaches gain experience and further develop as leaders from the crisis event. It transpires from such a conceptualization that the crisis is an unexpected event with salience as it depends on coaches' subjective evaluation of an objective event. Coach leadership often focus on coaches' behaviors (Bormann and Rowold, 2016; Arthur et al., 2017; Cotterill and Fransen, 2021). Wu et al. (2021)'s co-word analysis also revealed that leadership behaviors are the most published topic. Therefore, to address crisis leadership focusing on coaches *per se* and the topic of leadership behaviors, our research aims to investigate coaches' opinion patterns on effective leadership behaviors during the COVID-19 pandemic. We hypothesize that the different phases of the COVID-19 pandemic demand sports coaches to vary their leadership roles and/or have various countermeasures. At a practical level, this study provides experience and reference for coaches to respond to potential crisis events in the future. Any event that meets the three elements of a crisis mentioned above can be categorized as a crisis event, not only limited to a global pandemic. Also, the current research expanded on sports population researched (Bratland-Sanda et al., 2021) by studying coaches' leadership behaviors around the COVID-19 pandemic, and contributed to the literature during the COVID-19 pandemic in the realm of sports.

Materials and methods

Q methodology

Since the current general definition of crisis leadership emphasizes leaders' subjectivity to evaluate objective crisis events, we applied the Q methodology for data collection and analysis to examine coaches' subjective viewpoints about coach leadership behaviors around the crisis time. Q methodology is a comprehensive approach for exploring human subjective viewpoints (McKeown and Thomas, 2013). One of the key characters is that Q-method emphasizes self-reference. As McKeown and Thomas (2013, p. 2) stated, "The primary purpose of undertaking a Q study is to discern people's perceptions of their world from the vantage point of self-reference. These viewpoints constitute the Q methodological understanding of subjectivity." The term subjectivity here is referred to "by which is meant simply an individual's personal point of view on any matter of personal or social importance" (Wolf, 2010, p. 250). For the purpose of this study, we will examine how frontline coaches view effective coach leadership behaviors in a crisis event. Specifically, coaches will sort a set of statements (coach leadership behaviors during crisis time) on a bipolar scale from −4 to +4, as shown in **Figure 1**. Participants can sort statements (Q-sample) using paper cards or online software, namely Q-sorting. The Q-sample can be developed by existing public resources (e.g., coaches' Tweets about their thoughts) or by in-person interviews with coaches. Our Q-sample was developed by interviewing because "In-person interviewing is most consistent with the principle of self-reference" (McKeown and Thomas, 2013, p. 3). Also, the statements generated from the interviews more realistically and accurately reflect how coaches respond to crises compared to inferring their behavior from other resources such as archived material (e.g., books and tweets). Last, our Q-sample was developed naturalistically (unstructured) as opposed to ready-made (structured) due to the current theory being underdeveloped (McKeown and Thomas, 2013). The validity of Q-method had been demonstrated in the content of sports (Chen, 1996; Harris, 2018), psychology (Watts and Stenner, 2014), and leadership (Podsakoff et al., 1990; Militello and Benham, 2010; Howard and Dhillon, 2021).

Q samples and participants

The study followed the Code of Practice on Investigations Involving Human Participants issued by Loughborough University (2021). Data collection commenced once the study was granted approval by the University Ethics Approvals Sub-Committee of the authors' institution. This study's purpose was communicated directly with participating coaches, mainly through LinkedIn. All participating coaches voluntarily joined the study on their own time. The Q-sample was developed by interviewing 13 frontline professional coaches in the UK (female =1, male =12) from both team and individual sports (e.g., football, swimming, and volleyball). They all experienced the entire COVID-19 pandemic from January 2020 to July 2021. They shared how they managed and dealt with behaviorally and psychologically during the COVID-19 pandemic. All online conversations were audio recorded, with the coaches' consent. The average interview length was 35 min, the maximum was 52 min, and the minimum duration was 25 min. All interviews were transcribed into 60 double-space pages of Microsoft Word files. Regarding the number of statements (Q samples), we were guided by Militello and Benham's (2010; Q sample = 33) published research in *Leadership Quarterly* and Gabor and Cristache (2021; Q sample = 30) published research in *Mathematics*. A total of 34 statements were extracted and categorized as pre, during and post-crisis themes. The process was repeated by the first author to ensure consistency and avoid under-sampling or oversampling (see **Table 1**).

An extensive person sample of 30–50 participants in the Q methodology is sufficient (McKeown and Thomas, 2013; Gabor and Cristache, 2021). Under the condition that the diversity of opinions is ensured, the Q method perfectly achieves the goal using a small number of samples (Militello and Benham, 2010; McKeown and Thomas, 2013; Gabor and Cristache, 2021). The selection of participants needs to be careful and to bring more subjectivity. A total of 32 full-time coaches (included

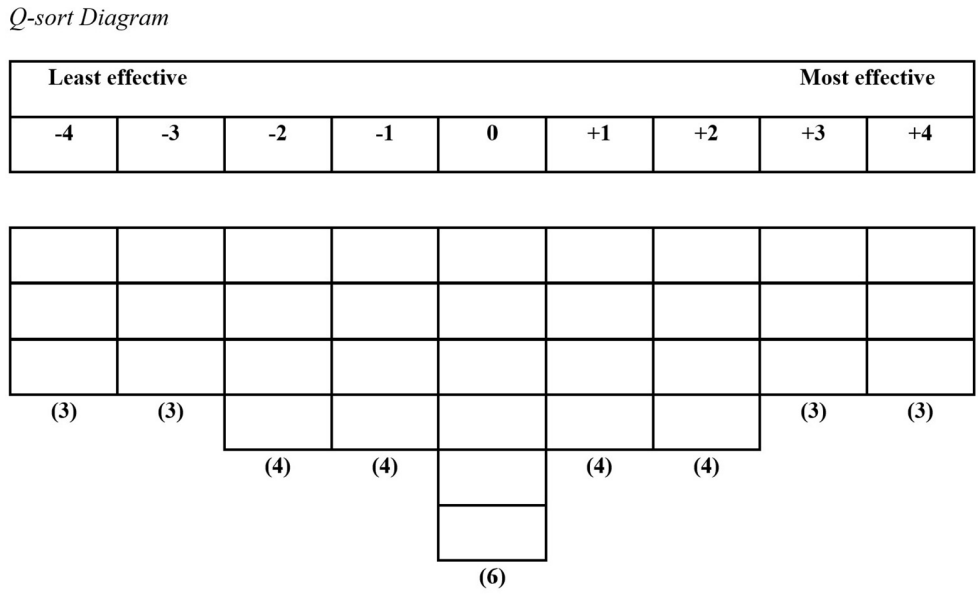

FIGURE 1
Q-sort diagram. Participants sorted statement (coaches' behaviors) into the grid from (−4) for the least effective behaviors, (0) for the neutral behaviors, to (+4) for the most effective behaviors.

interview phase coaches) from both individual and team sports (28 male and 4 female) who experienced the entire COVID-19 pandemic from January 2020 to July 2021 participated in the study. The age range was from 21 to 57 years old (SD = 10.16; mean = 31.34). The participants of this study represented sports included football (n = 11), rugby (n = 6), cricket (n = 3), swimming (n = 3), athletics (n = 3), volleyball (n = 2), basketball (n = 2), handball (n = 1), and table tennis (n = 1). About half of the participants (n = 15) coached at club level, the rest of the participants coached at international (n = 7), national (n = 7), and university (n = 3) level.

Administering the Q sort

Due to the social restriction imposed by the COVID-19 pandemic, all sorting was administered through a "Q method software" (Wired Solutions, Windsor, ON, Canada) (Lutfallah and Buchanan, 2019). The software allows respondents to conveniently sort using a web browser. Coaches received a detailed introduction through text and video (2 min) by the software. First, coaches have a familiarization phase, in which they assembled and sorted the statements into three initial categories–most effective, neutral, and least effective behaviors before finalizing the sorting. Then, coaches sorted statements into the grid displayed in **Figure 1** using (−4) for the least effective behaviors and (+4) for most effective behaviors. Thirty-two independent diagrams identical to **Figure 1** were generated, representing each coach' point of view. The average sorting time was 20 min, ranging from 18 to 22 min.

Statistical analysis

Q methodology used centroid analysis to find correlation matrixes among the 32 Q-sorts, and Varimax rotation was applied to maximize the variance of the extracted patterns (Watts and Stenner, 2012; Gabor and Cristache, 2021). Six patterns with an eigenvalue greater than one (Watts and Stenner, 2012; Gabor and Cristache, 2021) were extracted and rotated, which explained a total of 49% of the study variance. All patterns' composite fidelity meets the cut-off of 0.8 for explaining purpose (Gabor and Cristache, 2021). Each patterns implied a group of participants who shared similar opinions about the topic (Watts and Stenner, 2012). In our case, each pattern (or named factor) implied a group of coaches who had similar viewpoints about coach leadership behaviors around crisis time. Due to space constraints, we report the sorting value scores of each statement within each one of the three chronological patterns in **Table 1** (value from −4 to +4) rather than attaching six sorting diagrams. Each pattern pre, during and post-crisis stages is explained next.

Results

Overall, most of the coaches viewed behaviors in the during-crisis phase as the most effective behaviors. In contrast, pre-and post-crisis phase behaviors are either treated as less effective or not essential. Moreover, a close examinations indicated six patterns emerged describing the coach crisis leadership, namely,

TABLE 1 Statements scores for each pattern.

#	Q-sample (statements of Q-sorts)	Patterns					
		1	2	3	4	5	6
1	Pre: Control the number of coaching team members (decision-makers) to be 3 or less	−2	−4	−3	−2	−4	0
2	Pre: Early acceptance of the significance of the crisis and start communicating with others regarding the crisis	0	−1	−2	3	−1	−3
3	Pre: Be transparent and clear when informing athletes about the crisis	3	−3	2	−1	−2	1
4	Pre: Always maintain a non-antagonistic and safe team culture	0	0	0	1	4	1
5	Pre: Reassure players we (the coaches) are still there, and we are still a team	3	2	1	0	−1	4
6	Pre: Prepare training program despite of compromises and limitations	2	3	0	−1	0	−2
7	Pre: Gather/update information about the COVID-19 pandemic from other sources before it hit the UK	−2	2	−2	0	−3	−2
8	Pre: See what other teams were doing, pause, and think	0	−1	−3	−1	−3	−1
9	Pre: Don't panic, don't rush, calm down, and discuss in meetings. It's okay to have a break	1	−1	−2	3	3	−3
10	Pre: Clear assignment of responsibility to other team members (e.g., physio, captain)	3	0	0	−2	−3	−1
11	During: Be reactive instead of proactive	−3	−3	−4	−3	−2	−3
12	During: Organize team social activities to involve players (e.g., running group for charity, online quiz)	2	0	−1	−2	4	0
13	During: Consult professional advice and be strict about it	−1	−2	−1	2	−2	−4
14	During: Make sure athletes are able to access training resources all the time and not feel left out	1	1	4	4	3	2
15	During: Provide a suitable online platform for athletes to come and talk freely	0	2	0	0	1	3
16	During: Check on individual athletes regularly (e.g., phone call or message)	4	−2	2	2	2	4
17	During: Keep a positive and optimistic attitude and not transmit negativity to athletes	4	4	1	0	2	1
18	During: Keep reminding athletes that it's their responsibility to maintain professionalism and to be ready to resume competing at moment notice	−2	−4	3	2	−4	−2
19	During: Physical training program was not to push athletes, focus on mental as much as physical	0	0	−4	4	1	0
20	During: Proactively communicate with athletes. If there are no updates, then tell athletes there are no updates, don't say nothing	2	−2	4	4	2	0
21	During: Don't expect much from the team	−4	−3	−4	−3	4	−4
22	During: Expand team training program to emphasize athletes/team development (e.g., invite seminar speakers)	−3	−1	2	1	−1	4
23	During: Be patient coping with crisis	1	1	1	−2	3	2
24	During: Discover hidden talents among athletes that could help other team members	−1	1	0	−3	0	−1
25	During: Design training program documents for athletes who cannot attend regular training sessions	0	0	4	1	−4	−1
26	During: Take up responsibility beyond usual coaching duties to better deal with the crisis	−1	−2	−3	0	1	1
27	During: Use feedback loop between coach and athlete to encourage coaching	−1	4	3	0	2	2
28	Post: Read guidelines from all relevant resources and plan how to come back	1	2	2	2	0	2
29	Post: Safe and guided return, not too much and too quickly	4	3	1	3	−1	0
30	Post: Restart normal intensity/competition as soon as possible	−4	−4	−1	−4	0	−4
31	Post: Continue to do effective new routines from crisis time (e.g., online session)	−4	1	−1	1	−2	3
32	Post: Offer different options of returning to training, let athletes choose how often they like to train	−3	4	−2	−4	0	−2
33	Post: Care more about how people are feeling and be emotional supporters	2	3	3	−1	1	3
34	Post: Ask others (e.g., athletes) to help manage	−2	0	0	−4	0	0

+4: most effective behaviors, −4: least effective behaviors, and 0: neutral behaviors.

division of labor, athlete centered, team-driven, consulting, safe environment, and online training (see **Figure 2**). Each pattern represents a group of coaches with similar opinion about effective and ineffective behaviors taking place at pre, during, and post-crisis phases. To summarize and name each pattern, we identified extreme statements (e.g., ±4) that differed most from other patterns, extracted the "distinguishing statements" provided by Q software, and as well as coaches' interview answers. An example of a distinguishing statement would be that statement 10 was only rated positive by the group of coaches represented by Pattern 1, whereas other groups of coaches rated statement 10 either negative or neutral (**Table 1**). Militello and Benham (2010) also suggested referencing other data (in our case, initial interview transcripts) would provide a rich data set to understand the area of crisis leadership research. We chose to interpret the most prominent and unique points of coaches' view. The shared viewpoints, such as coaches should keep positive, would not be described every time. Following the reporting structure suggested by researchers (e.g., Watts and Stenner, 2012), the details of each pattern which represents

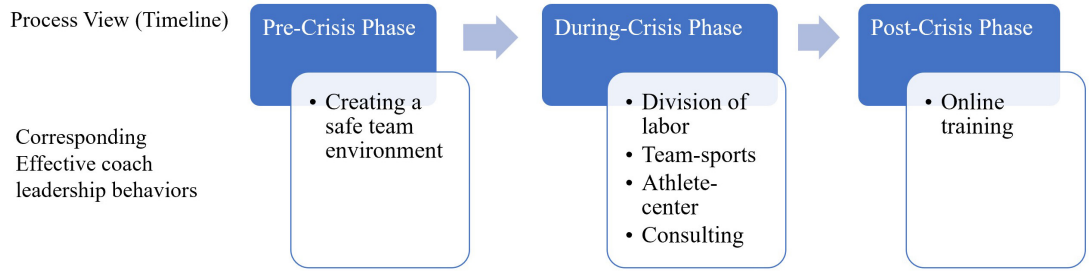

FIGURE 2
Six pattern of effective coach crisis leadership behaviors with a process view.

similar opinions shared by a group of coaches, are presented below.

Pattern 1 referred to *division of labor*. This pattern had an eigenvalue of 7.65 and explained 24% of the study variance. Six male coaches from individual and team sports with an average age of 29 are significantly associated with this pattern. These coaches, affiliated with different coaching levels, strongly believed their coaching philosophy. As leaders, they had clear plans for team members. First, before the start of a crisis, they were the only group placing emphasis on assigning responsibilities to the team members (statements 10: +3). Coach #1 commented: "Because we cannot train athletes as we used to, we gave control over the program to the physio and S and C (strength and conditioning) coach. That's one of the most effective behaviors we did. Both the physio and S and C coaches put some programs together so that athletes can come online and train in some way." Focusing on how other teams cope or gather information about the pandemic was regarded as inefficient behaviors (statement 7: −2; statement 8: 0). Second, during a crisis, they were the only group of coaches who did not like to receive feedback from athletes to help their coaching (statement 27: −1) and rated such behavior ineffective. Finally, they resumed pre-pandemic training routines and were not in favor of applying the practices employed during the crisis times to post-pandemic times (statement 31: −4).

Pattern 2 referred to the notion of *athlete centered*. This pattern had an eigenvalue of 1.78 and explained 6% of the study variance. Two individual sports (triathlon and swimming) coaches with an average age of 53 were significantly associated with this pattern. They revealed an athlete-centered viewpoint to guide coaches' behaviors. They coached at the club and international levels. In the pre-stage, they believed actions were more effective than psychologically accepting the severity of the crisis or using relaxed state of mind (statement 2, 9: −1; 6: +3). Specifically, they reassured the athletes that the coaches would get through this crisis with everyone (statement 5: +2). Also, they actively collected information and data about crisis events to prepare adequately for subsequent training (statement 7: +2; 6: +3). However, the transparency of crisis events is limited to the coaching staff, and letting athletes know too much about crisis events was considered ineffective leadership behavior (statement 3: −3). During the crisis stage, they chose not to put too much pressure on athletes. Such attitude is reflected in the fact that they neither checked the athletes' status regularly nor consulted other professional opinions to manage the team with a strict regime in place (statement 16, 13: −2). Instead of putting themselves into multiple roles (statement 26: −2), they patiently discovered athletes' abilities to help the team (statement 24: +1). In the post-stage, they also choose to return to regular training safely, but they gave athletes autonomy to decide how they preferred to return to regular practice (statement 32: +4), which is different from the views of all other coaches. As coach #2 commented: "The pandemic changed a number of rules, like how you engage with the athletes. In this kind of strange time, the real and positive behavior from my end is that when we set everything up, make things available for athletes to choose to come, not imposing them."

Pattern 3 referred to *team driven*. This pattern had an eigenvalue of 1.92 and explained 6% of the study variance. Four team sports (2x football and 2x rugby) male coaches with an average age of 28 were significantly associated with this pattern. The results are in stark contrast to Pattern 2's individual-sport coaches. From a team perspective, giving athletes flexible options to return to training is ineffective in their view (statement 32: −2). Their behaviors were team driven. Coaching a number of athletes at once make team-sports coaches very proactive, and reactive behaviors are unacceptable (statement 20: +4; 11: −4). Team driven coaches kept reminding athletes to maintain a high-performance status (statement 18: +3) and designed training plans involving everyone–not individualized training/coaching (statement 25: +4). As coach #3 commented: "As a team, we're trying to reassure everybody will be back soon. This is only temporary. Please don't lose sight of preparing for a season. The other teams who are also affected will also be working hard to be ready, so we can't afford to take a rest period." Last, team coaches focused on emotional support for athletes and have studied the return process in the post-crisis phase (statement 33: +3).

Pattern 4 referred to *consulting*. It had an eigenvalue of 1.50 and explained 6% of the study variance. Five coaches with an

average age of 34 were significantly associated with this pattern. Three out of the five coaches coached at the international level and showed a lot of unique behaviors. Accepting the significance of a crisis event was an effective behavior (statement 2: +3) and having a relaxed mind (statement: 9: +3) was also different from other groups. They are the only coaching staff that consulted other professionals and strictly followed them (statement 13: +2). As coach #4 commented: "Club doctors and our head physio gave us some excellent education on its (COVID's) seriousness and the impact it could have on all of our lives. We did what we needed to do to respect that and look after our players and our coaching staff." They are also the only group of coaches who expressed a great deal of care about athletes' mental as much as physical health (statement 19: +4).

Pattern 5 referred to the creation of a *safe environment*. It had an eigenvalue of 1.53 and explained 5% of the study variance. Three male coaches with an average age of 27 were significantly associated with this pattern. They were a group of coaches focused on building a safe team environment. Thus, they were the only group that considered the value of developing and maintaining a safe social environment (statement 4: +4) and organized team social activities as an effective behavior (statement 12: +4). As coach #5 commented: "If your teams were doing well, they tend to get on better. Our group had a good vibe, and we started having quizzes and just social nights. Or we do quizzes online, which was probably one of the most effective behaviors straight from the get-go." Last, these team safety-oriented coaches also kept a relaxed mind (statement 9: +3) as an effective pre-crisis behavior which only showed in international-level coaches' patterns (Pattern 4).

Pattern 6 referred to online coaching and had an eigenvalue of 1.17 and explained 5% of the study variance. Four younger coaches with an average age of 23 years were significantly associated with this pattern. They were the only group of coaches willing to expand training content (e.g., online session) used during the crisis event to post-crisis phase (statement 31: +3). As coach #6 commented "I think there's no reason why it can't be included. But don't overdo it. I'll put on an online session that maybe lasts 30 min. When I've got a different team this season that, changes things slightly because you have to get to know your players again. Have an online session where we talk about what we want to achieve." This group of coaches also made conscious efforts to bond with their athletes since they were willing to build a suitable online communication platform (statement 15: +3). In addition, reading the safe guide and relevant resources would be an intelligent choice (statement 28: +2). Also, our results indicated that giving more emotional support was one of the effective behaviors (statement 33: +3). This might be because not everyone in the team is ready, such as the athletes got infected with COVID-19 suffered more than others.

Discussion

The purpose of this study was to investigate frontline coaches' perspectives on what constitutes effective leadership behaviors, and the patterns of opinions coaches held during the COVID-19 pandemic. Six patterns emerged from the Q-method analysis capturing coaches' process views of the crisis event (pre, during, and post) on effective leadership behaviors, namely (1) division of labor, (2) athlete-centered, (3) team sport, (4) consulting, (5) safe environment, and (6) online coaching. The following sections explain the application of these patterns within the three chronological phases (pre, during, and post) and discuss how coaches can quickly and practically adapt to crises, minimize the disruption during a crisis event and gain useful experience after a crisis event (Wu et al., 2021).

First, examining coach crisis leadership in a process view can inspire coaches to understand how to prepare for future crisis events in an orderly and efficient fashion. From our interview and Q-sorting results, building and maintaining a safe team environment is the most effective behavior in the pre-crisis phase. Such results aligned with the recent research about the importance of coaches in creating a psychologically safe team (Fransen et al., 2020; Gosai et al., 2021). The unexpectedness of crisis events often does not allow coaches sufficient amount of time to adjust their behaviors and make decisions. Such a situation could be a major test for coaches to establish a safe team environment which will benefit team members to prepare for crisis events without panic. Coach leadership is an antecedent for athletes' and sports practitioners' psychological safety (Fransen et al., 2020). Coaches who were perceived with more coach leadership behaviors were more likely to make team members feel psychological safety (Gosai et al., 2021). In addition, coaches are one of the directly affected sports practitioners by crisis events, they also need to balance their team and life (Taku and Arai, 2020). Therefore, maintaining a united and non-antagonistic team would serve as the most reliable measure to help coaches minimize the fear of the crisis. To achieve a harmonious sports team environment, coaches were advised to build and sustain quality coach-athlete relationships (Jowett, 2017; Jowett and Slade, 2021). Coaches and athletes are two core sports practitioners; a quality coach-athlete relationship can help them stand together and increase team cohesion (Hampson and Jowett, 2014) and collective efficacy (Jowett and Chaundy, 2004).

Second, coaches mainly focus on minimizing or reducing the damage caused by crisis events in this phase. The biggest challenge identified by coaches was the lockdown policy which potentially made the team members lose their sports practitioners' identity and hindered psychological connections (Henriksen et al., 2020; Schinke et al., 2020). When the coaches are in a vulnerable situation, they used their leadership attributes to assign and empower the corresponding professionals to

help the team through the difficulties. Therefore, coaches assigned different tasks to team members and consulted other professionals, such as medical advisors. Under the remote training model, coaches could not maintain sufficient communication, which would increase conflicts between coaches and athletes (Wachsmuth et al., 2018). Thus, seeking outside expertise would be a wise choice. Coaches also recommend actively engaging with athletes, in which team-sports coaches designed and provided training resources for all athletes. Such result endorsed the research that group-based training increases athletes' ability (Pedersen et al., 2021) and athletes coped better when provided training programs (Fox-Harding et al., 2021). Another effective measure for coaches with plans and are athlete-centered is mainly to focus on keeping positive and do not transmit the negativity to team members. Such behaviors can decrease the pressure on team members since athletes already suffer depression in this stage due to game opportunities being withdrawn and other concerns (Lambert et al., 2022). Coaches also are advised to encourage athletes to join social activities to increase physical activity at home, such as encouraging athletes to upload their plank challenge videos to the team's social media group. This is an effective measure since sharing one's fitness image on social media promotes fitness activities (Godefroy, 2020).

Last, the post-crisis phase mainly concerned maximizing the learning experience after the COVID-19 pandemic. Overall, coaches agreed that a quick return is inefficient. After just experiencing a crisis event, active performers need to adapt to the new environment and the corresponding changes (Samuel et al., 2020). The sixth patterns of coaches' crisis leadership behaviors aligned with previous research findings about effective measures during the COVID-19 pandemic, such as online training (Moreno-Tenas et al., 2021). The sixth pattern revealed that coaches acknowledged the efficiency of online training during home confinement and continued to use the online training in their normal training program post-crisis. Such findings also demonstrated a crisis event can be transformed into an opportunity if one handled it properly (James et al., 2011; Taku and Arai, 2020). It is also worth noting that younger coaches (average of 23 years old) are more likely to embrace new training programs developed during the crisis compared to other coaches who choose to go back to previous training routines. Such results also warrant future research focusing on the differences and consequences of the age of coaches on crisis event handling. The disruption caused by the crisis event challenged coaches' training routines and pushed coaches to adjust their coaching behaviors, but not every coach is willing to adapt the changes. The age of the sport's practitioners can make a big difference psychologically during a crisis event. A study (Turner et al., 2021) demonstrated that senior athletes did not have significantly negative emotions during the COVID-19 pandemic even with a lack of matches. In contrast, the anxiety and depression of college students increased significantly due to absence of physical exercise (Xiang et al., 2020). Coaches, as the core member of the team, should maintain a healthy mental state to better influence their team members. Therefore, more research is encouraged to focus on the impact the age and experience of coaches on crisis events and the corresponding countermeasures and means.

Limitation and recommendation

The current study used Q-method to examine the coaches' views on effective leadership behaviors which aligned with the subjectivity in the definition of crisis leadership. It also needs to note that there are many other research agenda for coach crisis leadership. First, the coach crisis leadership can be studied in other context that meets the three criteria of crisis, a global pandemic is only one type of crisis. Also, the study sample mainly reflects the male coaches' crisis leadership behaviors due to limited female coaches' participants. The systematic discussion of crisis leadership has just begun, and more research and work need to be contributed to this field. For example, future research is recommended to discuss the connection between crisis leadership and established leadership theories. Wu et al. (2021) indicated the utility of transformational leadership in the context of crisis. Our result also endorsed such findings where coaches proactively support and interact with athletes during the crisis phase is consistent with the individualized consideration behavior of transformational leadership. Future research could further discuss the application of established leadership models and theories to crisis leadership. Second, the interview and Q-sorting data in this study were all from coaches. Future studies could also consider the views of athletes and other team members about perceived coach crisis leadership behaviors as a way to compare the extent to which the athlete and coach data and corresponding results align. While Q-method is an appropriate exploratory approach to investigate coach crisis leadership, future research is recommended to apply other conventional methods such as multivariate and regressive statistical inferential approaches (Flores et al., 2022; Teixeira et al., 2022) to further develop this topic. Last, researchers could observe the positive effects generated from the crisis event. For example, examine the difference and influence between coaches who continue to coach online and abandon online coaching. Spotting the positive effects of a crisis event is as important as dealing with a crisis event effectively.

Conclusion

The current study revealed coaches' effective leadership behaviors patterns around the time of crisis. With a process view, sports coaches can conduct various measures to deal with

evolving demands of team members in the pre, during, and post-crisis time phases. Results from coaches' view patterns revealed that building a psychologically safe environment is the most effective measure to confront a crisis event. Keeping a positive attitude and proactively interacting with other sports practitioners would minimize the damage during a crisis. Introducing new activities to regular training routines, such as online training, would maximize the learning experience from a crisis event. The applications of crisis coach leadership behaviors can apply to any event that meets the criteria of a crisis event. Given the critical role of coach leadership and the context of crisis, more research involving diverse participants such as athletes and other methodological approaches would further promote our knowledge of how coaches can handle potential crisis events.

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 Loughborough University Ethics Approvals Sub-Committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CZ contributed to the design, implementation, and analysis of the results. CZ and SJ contributed to wrote the manuscript and approved the submitted version.

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Conflict of interest

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

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"We missed the psychological support": A case study about the preparation of the Brazilian bronze medal kata team for the 2019 Pan American Games

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Purpose: The main aim of the study was to describe the key factors involved in the preparation process of the Brazilian bronze medal kata team for the 2019 Pan American Games, focusing on the athletes' perceptions.

Methods: Three male athletes from the Brazilian team performed a semistructured interview to identify the following topics: specific time for preparation, training organization, supplementary support, and perception and suggestion about the efficiency of the preparation process.

Results: Data from interviews were gathered and coded, and the major themes were summarized as follows after performing content analysis of the data: (a) technical and tactical training took the major part of the preparation; (b) the high level of the coaches helped the team to reach the technical quality of the kata; (c) better psychological support during the preparation could improve the athletes' performance during the training and competition; and (d) the lack of financial support compromised the commitment of the athletes during the training routine.

Conclusion: We concluded, based on the athletes' perception, that the most positive factor during preparation for a major competition was the high amount of time focused on technical-tactical training. Even with limitations to performing the physical training, the athletes recognized the importance of the physical component, to increase performance. Financial and psychological support could have helped the team to reach a better result (gold medal) attenuating the training distress.

KEYWORDS

qualitative, karate, kata, Pan American Games, training

Introduction

Karate is an ancient martial art that originated on the island of Okinawa, South of Japan, and was recognized as a martial art at the beginning of the 20th century (Arriaza, 2009). Besides the martial art characteristics, karate is also a competitive sport modality, organized by the World Karate Federation (WKF) since 1970, a maximal organization related to the International Olympic Committee. Karate can be divided into two categories: Kumite and Kata. Kumite is a technical combat category between two athletes characterized by high-intensity 3-min bouts involving kicking, punching, and quick horizontal displacements with no knockout allowed. The winning is based on scores obtained according to correct techniques applied against the opponent. Kumite athletes can compete individually and in teams of both sexes (World Karate Federation [WKF], 2017; Chaabene et al., 2019). Kata competition is described as an intermittent demonstration of offensive and defensive karate techniques that represents actual fights against fictitious opponents. Kata athletes (men or women) can compete either individually or synchronously in a team (three athletes per team) (World Karate Federation [WKF], 2017). Moreover, kata was created as a karate exercise in order to develop coordination and rhythm of the movements, to improve the karateka technique (Nakayama, 1973) and mental aspects such as concentration, focus, and discipline (Funakosh, 2014).

In the kata competition, seven referees evaluate the athlete's presentation considering athletic and technical criteria. Athletic criteria are based on strength, speed, and balance, and technical criteria consider the stances (i.e., leg postures), basic techniques, transitional movements, timing, correct breathing, focus ("*kime*"), and compliance with the style. There are four different styles called *Shotokan*, *Shito-ryu*, *Goju-ryu*, and *Wado-ryu* recognized by the WKF which compete together during official competitions. To compose the presentation, the athletes must perform one of the 102 kata from a WKF list (World Karate Federation [WKF], 2017). Usually, the most common kata performed in competitions lasts between 90 and 180 s (Lassalvia et al., 2021) and is chosen by the athletes according to their experience, level of difficulty, and opponent level (Augustovicova et al., 2018).

In high-level competitions, professional kata athletes usually have a long-term career presenting elevated technical-tactical skills and physical fitness components due to a higher amount of training hours. During the process of preparing for a competition, training is one of the main aspects necessary to achieve a successful result, together with complementary strategies for athletic health management (e.g., nutrition, physical therapy, and psychological support) (Issurin, 2010; McGuigan, 2017; Bompa and Buzzichelli, 2019). The complex combination of training factors used during the preparation process can play a key role in the success of the athlete in the competition (Bompa and Buzzichelli, 2019). However, this information in the kata discipline has yet to be described. Considering that the kata discipline is not frequent in the Olympic Games, continental competitions, such as Pan American in the American continent, represent one of the major international events in which a Brazilian kata athlete can compete. Therefore, understanding the preparation of kata athletes for this outstanding competition can bring important information to researchers, coaches, and athletes, given that the evidence in this sports discipline is still scarce. This study aimed to describe the key factors involved in the preparation process of the Brazilian bronze medal kata team for the 2019 Pan American Games, focusing on the athletes' perceptions.

Materials and methods

The case study utilized a qualitative approach, based on a semistructured interview to provide information about the phenomenon of interest. The case study approach allows for a better understanding of the athletes' experiences within a real-life context and involved with specific circumstances or incidents. However, case studies have limited generalizability (Stake, 2000; Patton, 2002). Moreover, the interview approach is often aimed at obtaining information or studying a particular field to answer the research question. Some studies in the field of exercise and sports medicine need to measure behavioral perspectives, such as athletes' motivation, attitudes, beliefs, and perceptions. Usually, these factors are difficult to measure without using qualitative research methods such as interviews. Qualitative methods are also useful in the study of contextual factors that affect physical activity and athletic performance (Draper, 2009). In the present study, the experts (i.e., kata athletes) are the key informants who have specific knowledge and skills, and for that reason, they become a source of information. Therefore, semistructured questions have been designed to explore the preparation process used by a bronze-medal Brazilian male kata team in the 2019 Pan American Games with open-ended questions to understand the key factors perceived by the athletes.

Participants

The participants consisted of three kata athletes that represented the Brazilian male team in the 2019 Pan American Games, winning a bronze medal (**Table 1**). The team was previously qualified due to succeeding in a specific competition to represent the team Brazil in the Pan American Games. The 2019 Pan American Games was held in Lima, Peru, with about 6,700 athletes participating in 39 sports and 61

TABLE 1 Athletes' description during the 2019 Pan American Games.

Code	Age (years)	Time training kata (years)	Time competing at a professional level (years)
Athlete 1 (A1)	25	15	10
Athlete 2 (A2)	19	10	8
Athlete 3 (A3)	25	20	15

disciplines. Twenty-two of these sports were qualifiers for the Tokyo 2020 Olympic Games. Kata competition occurred as a subdiscipline of karate, with individual and team competitions (LIMA, 2019). The study was reviewed and approved by the Ethics Committee from UNICENTRO University (Protocol 20449319.4.0000.0106), and the athletes signed the consent form before data collection.

Script of interview

Semistructured interviews were used to obtain an understanding of athletes' perceptions of the 2019 Pan American Games preparation. The questions were developed by three researchers: one researcher and former athlete of kata; one researcher with previous experience in qualitative design (e.g., semistructured interview) and training monitoring and prescription; and one researcher with experience in the training program who had contact with the athletes. The three researchers agreed to separate the questions into four categories for the analysis: (i) specific preparation for the 2019 Pan American Games; (ii) training organization; (iii) complementary support; and (iv) perception and suggestions about the efficiency of the training plan. At the end of the interview, athletes were asked "*Is there any question that was not asked, and you believe it should have been?*" (**Table 2**).

Interviewer and interview procedure

The three interviews were conducted by one researcher who had previous contact with the athletes, which allowed them to guide the interview using specific terminology associated with the training program and generate a comfortable environment with the interviewees. Interviews with experts were conducted online. More specifically, *Google meeting*® platform was used for the interviews to enable visual contact (i.e., video was kept on). Interviews lasted between 28 and 35 min and were recorded to be subsequently transcribed. The analysis and transcribed interviews were based on thematic coding to identify themes in qualitative data (Given, 2008). Then thematic analysis was performed according to what was proposed by Braun and Clarke (2021) and outlined in more detail under section "Data analysis." Transcripts were coded by two researchers who met after this process to discuss themes based on the highlighted codes. Instead of using a statistical quantifiable procedure to assess inter-coder reliability (e.g., percentage agreement, Cohen's Kappa, Krippendorff's Alpha), we opted to have researchers meeting and presenting to each other their views and interpretations with the ultimate goal to come up with a consensus of the main codes/themes. This procedure allows researchers' multiple perspectives of reality to be communicated and interpreted, and respects the diversity of their social context and personal history (Bauer et al., 2000). This approach also maximizes researchers' reflexivity and self-engagement with the qualitative nature of the research project (Yardley, 2008).

Data analysis

Qualitative data was based on content analysis, using six steps process for data engagement, coding, and theme development (Braun and Clarke, 2021): (i) data familiarization (reading and rereading the transcriptions of interviews); (ii) systematic data coding (coding the whole texts and identify the part of the texts which are answering the research questions); (iii) generating initial themes from coded and collated data (combined the data into four main themes); (iv) developing and reviewing themes (detailed analysis of the themes); (v) refining, defining and naming themes (name, split, combined, or discarded themes, confirming if research questions were answered); and (vi) writing the report.

The transcribed texts were analyzed using the qualitative data analysis software NVivo version 12 (QSR International Pty Ltd, 2018), and the transcription was made by the same researcher who performed the interviews and revised by a second researcher. Two researchers analyzed the verbal reports independently, and subsequently, the researchers determined themes and subthemes in each category. Themes are generally phrases or sentences that describe more complex and latent processes across the cases in the study (Saldana, 2013; Connelly and Peltzer, 2016).

Results

After the interview, the data was transcripted and coded, and the findings were expressed in themes and subthemes for each topic, described as follows:

Specific preparation for the 2019 Pan American Games

The athletes reported that the team was created approximately 1 year prior to the competitions to allow adequate preparation for the qualifiers of the 2019 Pan American Games. It was the first time that the team was put together with this particular formation (i.e., three athletes together). After the qualifying competition for the 2019 Pan American Games, the athletes reported that the training plan was organized and focused on correcting the mistakes that happened in the previous qualifying competition. In addition, the focus was on improving their performance in order to exhibit different technical skills that could increase their score and reach the gold medal. "*As much as we already knew which teams we were going to compete with, it was possible to get a sense of what we were missing, what we needed to improve (A2).*" "*We needed to improve physically and mentally (A3).*"

Training organization

At the beginning of the preparation, the coaches focused on the adaptation of the three athletes. "*In the beginning, it is about the adaptation of the three athletes (A3).*" As the team had a new formation and a large age range (i.e., A2 was 19 and A3 25 years old), the preparation started with strengthening the relationship among the three athletes and understanding the strengths and limitations of each one. "*A kata team does not depend only on you (A3).*" The choice of the kata performance was based on the best Kata performed by each athlete, in addition to what referees had previously scored the highest in other competitions. The physical performance component is prioritized in the male kata team, as well as the impact of each movement as they are executed. Therefore, "*the physical component was highly taken into consideration (A1).*" However, the technical component scores 70% of the total score, thus, the emphasis on the technique was higher during the training preparation. "*Even if the athlete is thin, when they perform the movement correctly, they stand out for the referees (A2).*"

Regarding the training organization, the athletes separated the training into two to three sessions per day, for physical and technical-tactical components. The training was performed every day, with only 1 day off (usually on Sundays). The physical component was trained individually and the technical-tactical sessions were performed by all athletes together with the coach (i.e., *sensei*). "*Each athlete chose the best schedule to do the physical training alone but the technical training should be done as a team (A3).*" "*We dedicated 30–40% of the total training time to perform a strength training program and the remaining was divided between 'kihom' and tactical training.*" Kihon is defined as one aspect of karate training and can be explained as technical training of all the strikes, stances, and displacements in order to improve the combination of power, balance, and coordination during the movements (Lassalvia et al., 2022). Two athletes had to work besides training (A1 and A2) and one athlete was an undergraduate student in Physical Education (A3). Considering their activities outside the training program, the physical sessions occurred according to the availability of each athlete. The athletes reported difficulties in fitting the physical sessions into their daily routines. "*I trained sometimes in the late evening or very early in the morning (A2).*" However, they recognized that the physical sessions played an important role in the preparation process for the 2019 Pan American Games compared to previous competitions.

Most parts of the training were devoted to the technical movements (kata) and "*kihon*" movements. These training sessions were performed with the three athletes together or individually with the coaches (*sensei*). Athlete A2 reported training sometimes four times per day. In the few weeks

TABLE 2 Structured interview questions.

Questions and prompts
Specific preparation for the 2019 Pan American Games
1. When did the team start the preparation for the qualifiers to compete in the 2019 Pan American Games?
2. When you learned that your team had been classified to compete in the 2019 Pan American Games, have you and/or your team thought about doing something different from what you were already doing to achieve a medal?
Training organization
3. Did you organize the training based on the technical scoring criteria to score higher in the competition?
4. Can you describe how you distribute the technical-tactical and physical components in the training preparation? E.g., per day, per period of the day (morning/afternoon), per week?
5. Can you rate the importance of the technical-tactical and physical components in your preparation?
6. Did you have any professional support during the training period? What was their role (i.e., technical-tactical or physical component)?
7. Did you have any conversation with your team or coach about the training efficiency? Did the training work as planned?
Complementary support
8. Did you have support for any professional in addition to training (e.g., physical therapist, nutritionist, psychologist)?
9. Did you have sponsors during the preparation period?
Training perception and further suggestions
10. Looking back at the preparatory period, what do you think that worked well and what would you do differently?
11. If you had to start a new training plan for an international championship, how would you structure it?
Is there any question that was not asked, and you believe it should had been? Is there any aspect of your training that you would like to highlight about the preparation period?

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immediately before the competition, the team focused on refining the movements (kata) and training every day with no day off. "*As the competition was getting close, our training was becoming more similar to the competition day, to be more realistic (A1).*" "*Our focus in technical training increased, since the three of us needed to perform exactly the same movement (A3).*" The athletes described that the technical session began to get longer in duration. The movements were recorded and analyzed by all athletes together, in order to correct their detail. "*Focus on correction and repetition for me is what will harmonize the movements between the three athletes (A2).*"

As regards professional support, the team had two coaches (*sensei*) who helped with the technical and tactical components, correcting the movements and supporting the kata composition. For the physical training, each athlete had support from different professionals (i.e., personal trainer) who was not specialized in exercise prescription for professional athletes.

Complementary support

During the preparatory period, the team described partnerships with professionals in the fields of physical therapy, nutrition, and psychology, in which they were treated with no additional financial costs. Athletes A1 and A3 reported they had a few injuries during the process, and they received physical therapy support from a private clinic with no costs to treat the injuries and mitigate the risk of future ones. Nutrition counseling was reported as insufficient during the training process. Regarding psychological support, athletes A2 already had long-term assistance and athletes A1 and A3 had support from a psychologist from the Brazilian Olympic Committee close to the competition.

Neither the team nor the individual athletes had a sponsor for full-time training during the preparation. The athletes reported only specific financial support to move from one city to another during the classification competitions and to go to the Brazilian Olympic Center (Rio de Janeiro) before traveling to Lima, for the Pan American Games. The lack of financial support was pointed out by the athletes as one of the major negative factors during the preparation process. "*If we had better support from the country and if A1 and A2 did not need to work during the preparation, they would have more time to dedicated for improve their nutrition habits. The lack of time negatively influenced the preparation process (A3).*" "*A sponsorship at the Brazilian Team level would be a sponsor that stays with the athlete during the whole year. The athlete needs to pay for their own nutrition supplementation and facilities to perform the strength training (A2).*" The athletes informed that the support from Brazilian Olympic Committee comes only after winning a medal in an international competition. "*I never understood well, you need to be the best to receive something, but how can you win if you do not have support?*"

Training perception and further suggestions

Regarding the training process, the athletes described that they should have performed more tests before starting the training plan, and structured the session according to the components that needed to be improved. Athlete A3 describes that a baseline evaluation before starting the preparation process could help in planning the training sessions. "*First step, I would perform physical tests to see how we are doing, to have a baseline parameter. I would perform a kata evaluation to see how we are, if we remember the timing (movements) and if we are still aligned. From these first evaluations (physical and technical), develop the specific training of the modality and the physical components according to the initial. That is what I would think.*" Similarly, athlete A2 reported "*I think, I would perform tests, in order to know if someone on the team had some injuries or something like that. And I would build strength training based on the results.*" The positive aspect of the training planning was the technical-tactical preparation. The athletes recognized that they were performing high-quality technical-tactical components due to the coaches' expertise and their long-time experience and successful results in the discipline. "*I think that the technical sessions were well structured. We performed the 'kihon' with the team and then with the coaches individually. I believe that worked out very well (A2).*"

When asked about what they suggest for the preparation process, the athletes described that they would invest in factors such as improving the resting/recovery period during the process, improving the quality of the diet, and seek for psychological support. The psychological aspect was extensively explored by the athletes, highlighting the lacking of psychological support for the team during the preparation. "*Perhaps a psychologist as part of the staff of our team could have made a significant difference to achieve a better result (e.g., the gold medal).*" According to the athletes, the Pan American Games can be considered one of the most important competitions for Brazilian kata athletes, therefore, the pressure during the preparation was very high, significantly requiring psychological preparation. "*It was highly mentally exhaustive (A2).*" "*Most of the time, it was not our body that was tired, it was more the mind because it was a lot, a lot of pressure (A3).*" "*I would not change the physical or technical preparation; however, I would be more relaxed during this process (A2).*"

Moreover, the athletes pointed out the benefits of seeing each other frequently. The fact of being always together, every day for almost 1 year, was one more factor to justify the need for psychological support. The athletes compared their relationship to a marriage, "*We had argument and disagreement, but also needed to support each other (A1).*" During this period, the support of a psychologist for the three athletes together, as a "couple therapy" could help in a better coexistence. "*If we have support from a psychologist since the beginning, as a therapist for*

couples, but instead for the team, we could certainly have been able to perform more in all the training sessions and probably perform better in the competition (A3)."

Is there any question that was not asked, and you believe it should have been? Is there any aspect of your training that you would like to highlight about the preparation period?

When asked at the end of the interview if the athletes would like to add any point that was not addressed in the interview, athlete A1 point out "*The psychological part. I think is a very important part, that the athlete should focus a lot, especially high-performance athletes (A1).*" The athlete A3 highlighted the importance of technical-tactical preparation. "*I think we did not comment about the level of instruction that we (the team) received. I believe that the level of instruction (from the coaches) was very high, and it favored a lot. Because there were teams stronger than us, but technically we were superior. So technical instruction is a crucial point, in preparation (A3).*" The athlete A3 also highlights that kata is a modality whose strongest point is the technical factor and makes an analogy with soccer "*for soccer the important thing is not how perfect the pass is, it is important to make the ball come to the teammate*." In the kata discipline, technical performance is a key element.

Figure 1 summarizes the key factors described by the athletes to improve the preparation process for major competitions for the kata team. According to their experience in the 2019 Pan American Games, it was possible to identify in the interview some recommendations about training organization, technical-tactical training, complementary support, and psychological support.

Discussion

This present study aimed to describe the key factors involved in the preparation process of the Brazilian bronze medal kata team for the 2019 Pan American Games, focusing on the athletes' perception. The main findings, according to the interview analysis were: (a) technical and tactical training took the major part of the preparation; (b) the high level of the coaches helped the team to reach the technical quality of the kata; (c) better psychological support during the preparation could improve the athletes' performance during the training and competition; and (d) the lack of financial support compromised the commitment of the athletes during the training routine. The findings reinforce the extant literature while enhancing knowledge of the kata discipline in the context of the training and complementary support in which the article is grounded.

To plan an annual cycle is necessary to pay attention to principles related to the training process in order to focus on sport-specific needs to ensure optimal preparation for competition. Regarding the training process, the main aim is to *induce physiological adaptation and maximize performance at a specific point in time (the main competition)*. Each sport had a specific dominant factor to be training, therefore, the phases of preparation (general and specific) can be distinctive, the suggestion that non-specific training (e.g., general physical conditioning) can be introduced initially, and more specific tactical and technical training occurring more frequently when the main competition approaches (Plisk and Stone, 2003; Bompa and Buzzichelli, 2019). This concept has been endorsed previously in the periodization of mix-martial arts (James et al., 2013), and supported by the Brazilian kata team. This underpins the athletes' description in the interview that during the training process, the technical and tactical components took a major part, and the high level of the coaches make a difference in improving the kata performance during the competition. The athletes did not deliberate adequate time for physical training during the process, and the restricted period for physical training could be related to a lack of time to fit the training into the daily routine. Even with some limitations to performing the physical training, the athletes recognized the importance of the physical component in the final performance. Recently, a scoping review showed that kata practice can improve cardiorespiratory fitness (Lassalvia et al., 2022), thus, it is possible to speculate that the physical components of the athletes were well-stimulated with the technical and physical session, even though the physical session was in lower proportion.

An important aspect mentioned by the athletes during the interview was financial support. Two athletes (A1 and A2) reported having jobs to support their affairs, training (e.g., gym memberships), and nutritional supplementation. Also, the lack of financial support led the athletes to spend time on the job (outside the sports context), affecting the time to perform physical training. Naturally, time spent on work obligations could affect the training plan in daily and weekly cycles, which may negatively affect the potential of load adaptation and the quality and speed of recovery. Indeed, financial support is one of the big issues among high-level athletes. A recent study interviewed 20 retired Olympic athletes from different sports modalities representing six different countries (Japan, Mexico, Portugal, Singapore, Republic of Korea, and the UK), and demonstrated that all athletes experienced financial challenges and struggles. Asking about the coping strategies to overcome their financial challenges, the athletes reported part-time jobs and training focused on medals and high ranks, which is likely to result in organizational financial support (Hong and Fraser, 2021). Similarly, Brazilian financial support for athletes is based on their results (medals) in competitions. The "*Bolsa Atleta*" is a program that directs resources from the Brazilian Ministry

FIGURE 1
The athletes' perception of the key factors during the preparation process for major kata competitions.

of Sports to athletes who reached the podium in national and international competitions (Brasil, 2004). However, as pointed out by athlete A3, "*is necessary to win to receive the financial resource, and how you can win with you do not have the adequate resource to improve your performance?*"

In addition to the training plan, the readiness of the athlete or the team for competition involves a complex interaction of factors such as well-planned nutrition, management of injuries, and psychological responses (Bompa and Buzzichelli, 2019). The athletes reported a lack of support on nutritional and psychological aspects throughout the process. The psychological aspect, however, was the most mentioned during the interview. The psychological demands in high-level sports settings can be related to the elevated competitive pressure, high training load, increased performance expectations, and numerous transitional events that can represent a significant threat to athletes' mental health (Henriksen et al., 2020). The pressure to perform a high-quality kata routine could trigger mental health impairment in the athletes. Indeed, all athletes highlighted the necessity of a psychological follow-up during the process, to minimize the demand of the training and the stress of the competition. The recent literature has discussed and recommended strategies during the preparation process (pre-games phase) to take care of mental health issues in athletes, and promote self-care for the athletic population as well as coaches and staff to reduce unnecessary distress (Henriksen et al., 2020). Thus, the present study highlights the importance of mental health intervention in the kata discipline as well.

One limitation of our study is the assessment of one kata team only. The case study approach is limited to a specific population, thus the results should be interpreted with caution and cannot be extrapolated to other contexts and other countries/teams. The present study assessed three athletes. A previous case study in sport science can vary from one athlete (Hare et al., 2008) to a specific group of athletes (Kerr and Grange, 2009) showing important findings. Besides the limitations, to our knowledge, this is the first study describing the preparation process of a medal kata team for a major competition. Additionally, the interview presented a retrospective nature and was performed before the games could limit the memory of the events (Bryant et al., 2006). However, as the 2019 Pan American Games was one of the most important competitions in those athletes' careers, it is likely that they accurately recalled their preparation process. Finally, we did not incorporate any statistical analytical procedure to determine intra- and inter-coder reliability as we kept the qualitative nature of the coding/theming process. Future investigations could add both a qualitative and a quantitative procedure for coding reliability to improve the communicability of the coding frame.

Conclusion

In conclusion, based on the athletes' perception, the positive factor during the process of preparation for a major competition was the high amount of time focused on technical-tactical training. Even with some limitations to performing the physical training, the athletes recognized the importance of the physical component in the final performance. As areas raised by the athletes need more significant improvements in the future, financial and psychological support could have helped the

team to reach a better result (gold medal) by attenuating the training distress.

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 Unicentro (number: 3.594.757). The patients/participants provided their written informed consent to participate in this study.

Author contributions

ACP, CL, and DS: article conceptualization. ACP and CL: data selection. ACP, CL, and IM: data analysis. ACP, CL, IM, JC, and DS: drafted manuscript. All authors critically revised the manuscript, contributed to the article, and approved the submitted version.

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Conflict of interest

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

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Psychological skills training impacts autonomic nervous system responses to stress during sport-specific imagery: An exploratory study in junior elite shooters

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This study investigated the effects of psychological skills training (PST) in shooters psychophysiologically using heart rate variability (HRV) in addition to psychological questionnaires and participant interviews. Five junior pistol shooters participated in an 8-week PST program consisting of a group session per week followed by individual counseling. Before and after PST, we collected electrocardiography data during rest, mental imagery of sport-related crisis situations, and successful performance, to analyze differences in HRV indices. Participants also responded to the Psychological Skills Inventory for Archery and Shooting (PSIAS), Intrinsic Motivation Inventory (IMI), Sports Anxiety Scale (SAS), and Trait Sport Confidence Inventory (TSCI). Results showed that the perceived competence (pre: 2.52 ± 0.95, post: 3.36 ± 0.73, $p = 0.049$) and trait sport confidence (pre: 4.94 ± 1.17, post: 6.60 ± 0.65, $p = 0.049$) significantly improved after PST. The analysis of HRV indicated that the ratio of low-frequency power to high-frequency power (LF/HF ratio) decreased significantly during imagery of crisis (pre: 3.4 ± 2.3, post: 1.014 ± 0.71, $p = 0.038$) and success (pre: 1.933 ± 0.917, post: 0.988 ± 0.572, $p = 0.046$), reflecting a strengthened autonomic nervous system's responsiveness to stress. Our findings illustrate that PST can help athletes better cope with psychologically disturbed situations during competition, by providing psychophysiological evidence through HRV changes.

KEYWORDS

psychological skill training, shooting, heart rate variability, stress, imagery

1. Introduction

Successful performance in sports depends on three major components, namely, physical condition, motor skills, and psychological readiness (Yongtawee et al., 2022). Often, differences in psychological readiness or mental toughness among professional sports competitors who are highly skilled and physically fit can contribute significantly to determining whether they win or lose. According to the individual zone of optimal functioning (IZOF) model, athletes' performance can be successful when their pre-competition anxiety is within or close to their own optimal zone (Hanin, 2000). However, when the anxiety level falls outside of the individual optimal zone, performance suffers. Therefore, athletes try to stay in their IZOF through various mental techniques.

Recognizing the importance of mentality in sports performance, there has been an increase in professional psychological support for athletes.

Psychological skill training (PST) is a systematic practice that aims to help athletes acquire self-regulation skills for optimal performance (Vealey, 1988). PST comprises multiple strategies such as arousal regulation, anxiety management, goal setting, concentration, imagery, routine, and cognitive restructuring. Moreover, studies have underscored the benefits of PST for athletes in various sports including fencing (Heil and Zealand, 2001), tennis (Mamassis and Doganis, 2004), archery (Kim et al., 2021), baseball (Shin and Yoo, 2021), and shooting (Kim and Shun, 2010). In particular, closed-skill accuracy sports such as shooting occur in relatively stable environments wherein optimal performance is closely related to how athletes attune their arousal level and maintain focus on skill execution. Successful performance in a shooting context most likely depends on the stability of the firing sequence (i.e., aiming, breath control, movement control, trigger control, and follow-through) as opposed to physical abilities such as power and speed (Kim and Han, 1995). Therefore, to obtain a high score in shooting, technical factors such as posture, breathing, aiming stability, and firing time, and physical factors including endurance should align adequately with psychological factors such as concentration, confidence, and anxiety control.

To maximize the advantages of PST, adequate choice and use of evaluation tools are essential. Various assessments have been developed and used to measure the psychological aspects of athletes, including intrinsic motivation (McAuley et al., 1989), performance strategies (Thomas et al., 1999), competitive anxiety (Martens, 1977), and confidence (Vealey, 1986). These evaluation tools allow athletes, coaches, and sports psychologists to keep track of psychological status of athletes and may help them plan an optimized PST program for individual athletes or teams. However, these questionnaire-based assessments are limited in terms of capturing psychophysiological changes in real-time. Furthermore, the use of retrospective self-reports could yield responses that are subject to distortion. A meta-regression analysis of the effectiveness of PST and behavioral interventions in sports revealed positive publication bias (Barker et al., 2020). In addition to selective or distorted reporting, the overly positive effects of PST can also be due to placebo effects, reflecting high expectations or beliefs that beneficial treatment was received among athletes (Raglin et al., 2020). These limitations suggest the need to enhance objective indicators that demonstrate PST outcomes.

To this end, various biomarkers have been adopted in psychological research and other fields. For example, electroencephalography (EEG; Hung et al., 2008; Deeny et al., 2009; Lee et al., 2013) and functional magnetic resonance imaging (fMRI; Milton et al., 2008) provide information about real-time brain activation during skill execution. Furthermore, studies have also employed heart rate variability (HRV; Ortega and Wang, 2018) and electrodermal activity (EDA; Tremayne and Barry, 2001) as psychophysiological measures that reflect sympathetic and parasympathetic nervous system activities caused by physiological arousal.

HRV refers to the variation in the duration of the inter-beat interval of the heart (Strack, 2011) and is commonly used in sports science as a physiological marker of a person's emotional response (Appelhans and Luecken, 2006) and autonomic nervous system responsiveness to the demands of stressful situations (Wheat and Larkin, 2010). Furthermore, HRV decreases in circumstances that exacerbate stress or anxiety (Miu et al., 2009). Hence, fluctuations of HRV are inevitable during competitive sports events, especially in the presence of spectators. HRV during performance can also vary depending on the performance level. For example, Neumann and Thomas (2011) reported that experienced golfers exhibited higher levels of HRV than novice golfers during putting. In general, HRV shows a large variation in a psychologically stable state and a small variation in an unstable state. Experienced golfers have more automated putting motions compared to novices, being able to perform with relatively little effort. Therefore, it is possible that more skilled athletes demonstrate greater HRV reflecting a stable psychological state during performance.

Furthermore, HRV has been used widely in studies to verify the effects of psychological techniques and biofeedback training in various sports including golf (Lagos et al., 2011), basketball (Paul and Garg, 2012), short track (Beauchamp et al., 2012), and judo (Morales et al., 2013). However, there are limited studies that underscore the effects of PST on elite shooters. Moreover, previous studies reporting the effects of PST have focused on a single approach using psychological questionnaires (Sheard and Golby, 2006; Golby and Wood, 2016), interviews (Gucciardi et al., 2009; Sharp et al., 2013), or physiological indicators (Grosu et al., 2013; Slimani et al., 2017). Therefore, the present study intended to examine the effects of PST in junior elite shooters using objective and integrative measures by analyzing HRV in addition to self-report psychological questionnaires and participant interviews.

2. Materials and methods

2.1. Participants

This study comprised five junior air pistol shooters (three males and two females) aged 17 to 18 years. All participants had three to 4 years of shooting experience; however, none of the shooters had previously undertaken a structured PST package. Prior to participating in the study, the participants were informed of the purpose and procedure of the study including the contents of the 8-week PST program (Table 1). The participants provided written informed consent on their behalf and for their legal representatives. The study was conducted in accordance with the Declaration of Helsinki and following a confidentiality agreement.

2.2. Dependent variables

2.2.1. Heart rate variability

The PolyG-I (Laxtha Inc., Daejeon, Korea) was used to collect electrocardiography (ECG) data that could be used for HRV analysis in this study. For the ECG measurement, participants were accompanied individually to a sound-attenuated room where temperature and humidity were controlled. The participants were seated comfortably in a chair with electrodes attached to three body parts, namely, the palm side of both wrists and the right ankle. The ECG data were recorded for a total of 18 min, particularly 6 min each for three measurement conditions, namely, relaxation, imagery of crisis during competition, and imagery of successful performance. Data were obtained at a 512 Hz sampling rate and artifact-removed using a 60 Hz notch filter. Kubios HRV software (version 2.2) was used for further analyses of the HRV parameters.

HRV metrics (i.e., the variations in time intervals between adjacent heartbeats) can be divided into time-domain and frequency-domain parameters. In this study, the standard deviation of the N-N (SDNN) and root of mean squared difference of successive N-N intervals

TABLE 1 The content of the 8-week PST program developed in this study.

Session	Program	Details
1	Orientation	- Introduction to PST and the program overview
		- Why mental strategies matter
		- Understanding anxiety and arousal
2	Goal-setting	- Importance of goal-setting
		- Setting short-term and long-term goals
		- Setting process, performance, and outcome goals
3	Self-understanding	- Understanding individual psychological characteristics through self-exploration
		- Identifying individual cognitive/physiological characteristics
4	Imagery I	- Definition and concept of imagery
		- Effectiveness and importance of imagery training
		- The operational mechanism underlying imagery
5	Imagery II	- How to practice imagery
		- How to complete imagery training worksheet
6	Relaxation	- Breathing to regulate physiological arousal
		- Personalizing the training protocol for breathing relaxation
7	Cognitive restructuring	- Finding habits to mitigate negative thinking in competition and training
		- Replacing irrational beliefs with rational belief systems
		- Developing self-talk for situations
8	Routine	- Understanding the concept and different types of routine
		- Examples of routine-use in shooting events
		- Creating individual routines

(RMSSD) were used as time domain indices. Furthermore, low frequency (LF; 0.04–0.15 Hz), high frequency, (HF; 0.15–0.4 Hz), and LF/HF ratio (the ratio of LF to high-frequency HF power) as frequency domain indices were analyzed. The power of each frequency band was expressed as ms^2.

2.2.2. Psychological questionnaires

2.2.2.1. The psychological skills inventory for archery and shooting

The Korean version of the Psychological Skills Inventory for Archery and Shooting (PSIAS) was used in this study. The PSIAS consists of five sub-factors of psychological skills, namely imagery control, attention/anxiety, achievement motivation, arousal regulation, and confidence (Kim et al., 1999). Furthermore, the PSIAS comprises five items for each sub-factor, with a total of 25 items measured on a 7-point Likert scale, ranging from 1 (not at all) to 7 (very much). Moreover, this inventory was specifically developed to analyze the major psychological factors required for shooting. Thus, PSIAS is a useful tool to evaluate the psychological skill level of an athlete from which a personalized PST program can be constructed. The reliability of the PSIAS was re-ported in a previous study expressed by the Cronbach's alpha coefficient was 0.63 for imagery control, 0.78 for attention/anxiety, 0.85 for achievement motivation, 0.71 for arousal regulation, and 0.71 for confidence (Kim, 2001).

2.2.2.2. The intrinsic motivation inventory

The 16-item sport-oriented version of the Intrinsic Motivation Inventory (IMI) was used for this study. The IMI is a psychometric measure designed to assess an individual's level of intrinsic motivation in sports (McAuley et al., 1989). This instrument uses a 7-point Likert scale, ranging from 1 (not at all) to 7 (very much), and contains 16 items, comprising four items for four subscales: interest/enjoyment, perceived competence, effort/importance, and pressure/tension. Previous studies have reported the reliability of the IMI and found Cronbach's alpha coefficient values of 84 for interest/enjoyment, 0.94 for perceived competence, and 0.72 for pressure/tension (Lim and Kim, 2014).

2.2.2.3. The sports anxiety scale

The Sports Anxiety Scale (SAS) was developed by Smith et al. (1990) as a multidimensional measure of competitive trait anxiety experienced by athletes before or during competition. This 21-item questionnaire assesses somatic anxiety (nine items), worry (seven items), and concentration disruption (five items). The scale uses a 4-point Likert scale for responses, ranging from 1 (not at all) to 4 (very much). Cronbach's alpha coefficient of the SAS in a previous study was 0.92 for somatic anxiety, 0.86 for worry, and 0.81 for concentration disruption (Lee et al., 2020).

2.2.2.4. The trait sports confidence inventory

The Trait Sports Confidence Inventory (TSCI) was developed by Vealey (1986) to assess individual differences in the extent to which athletes feel confident in their ability to perform well. This inventory contains 13 items and uses a 9-point scale ranging from low confidence (score of 1) to high confidence (score of 9). The TSCI has established reliability with a Cronbach's alpha coefficient of 0.927 (Yang et al., 2015).

2.3. Psychological skills training program

Prior to the development of the PST program, we conducted an extensive literature review and consultations with the participating athletes and coaches to identify their demands. Thereafter, we organized a three-person expert group with a professor in sports psychology, a sports psychology counselor, and a shooting coach. After several discussions, a PST program was developed consisting of eight sessions of 50-min group training combined with 30-min individual counseling after each session (Table 1). The group session occurred on a fixed schedule, while the individual counseling schedule was adjusted according to the individual training schedules of the participants. All participants completed individual counseling within 48 h of the group session date. The participants were provided with worksheets relevant to the topic, excluding orientation. During individual counseling, participants were provided feedback on the content of the worksheet from the previous session. Furthermore, consultations with participants underscored the difficult aspects of applying the psychological skills they had learned to a real-life context. Moreover, the counselor in the study offered detailed guidance regarding the participants' personal traits and specific needs.

2.4. Procedure

After completing the informed consent form, all participants were instructed to respond to the psychological questionnaires which included a paper-and-pencil version of the PSIAS, IMI, SAS, and TSCI as baseline tests. Thereafter, the participants were individually escorted to a quiet room to perform baseline HRV measurements. Furthermore, participants were asked to rest comfortably while sitting in a chair with ECG electrodes attached to their bodies. ECG was recorded for 6 min each under several conditions, namely, comfort when breathing (relaxation), recalling of a previous crisis during a competition (crisis), and imagery of perfect performance (success). During this process, participants were allocated one-minute intervals between conditions to remove any influence of the preceding condition. Furthermore, the order of the conditions was randomized. Upon request, participants were allowed to rest until they were ready to move to the next condition. The PST session was conducted once a week for eight consecutive weeks. The program provided participants with education and training on psychological techniques and application methods as well as personalized feedback through individual counseling, which immediately followed the group session. After completing the 8-week course, post-tests for psychological variables and HRV were performed consistent with the baseline tests. Finally, the interviews conducted during individual counseling sessions were transcribed and used as qualitative data to interpret the results.

2.5. Data processing

To examine whether participation in PST for 8 weeks brought about any psychological changes, paired samples t-tests were administered with the scores on the psychological questionnaires serving as dependent variables and the measurement time (i.e., before and after PST) serving as an independent variable.

To examine any differences in HRV parameters before and after PST, paired-sample t-tests were performed separately for three measurement conditions: relaxation, imagery of crisis during competition, and imagery of successful performance, with the HRV values serving as dependent variables and the measurement time (i.e., before and after PST) serving as an independent variable. All statistical analyses were performed using SPSS Statistics 21, and the statistical significance level was set at $p = 0.05$. We used a two-tailed test for all statistical analyses and Cohen's d as a measure of effect size.

3. Results

3.1. Heart rate variability

We analyzed the HRV time-domain indices and found no significant main effect of time on SDNN in relaxation ($t = -2.479$, $p = 0.068$), crisis imagery ($t = -0.555$, $p = 0.608$), and success imagery ($t = -0.622$, $p = 0.567$) conditions and no significant pre/post differences on RMSSD in relaxation ($t = -1.493$, $p = 0.209$), crisis imagery ($t = -1.235$, $p = 0.284$), and success imagery ($t = -1.597$, $p = 0.185$) conditions. Among the frequency domain indices, the LF/HF ratio indicated significant main effects of time in the crisis imagery condition ($t = 3.029$, $p = 0.038$) and successful performance imagery condition ($t = 2.843$, $p = 0.046$), indicating a decreased low frequency (LF)/high frequency (HF) ratio after PST compared to pre-PST (Table 2; Figure 1). The pre/post difference in LF/HF ratio was not significant in the relaxation condition ($t = -0.689$, $p = 0.528$). Moreover, no significant differences were observed in the analyses of LF powers in relaxation ($t = -2.316$, $p = 0.081$), crisis imagery ($t = 0.979$, $p = 0.382$), and success imagery conditions ($t = -0.473$, $p = 0.66$). The analyses of HF powers in relaxation ($t = -0.282$, $p = 0.791$),

TABLE 2 Pre- and post-PST values of HRV parameters.

Situation	Parameter	Pre-test (mean ± SD)	Post-test (mean ± SD)	Paired *t*-test		
				t-value	*p*-value	Cohen's *d*
Relaxation	SDNN (ms)	69.14 ± 18.49	89.78 ± 25.46	−2.479	0.068	0.92
	RMSSD (ms)	46.6 ± 18.65	61.14 ± 18.8	−1.493	0.209	0.77
	LF power (ms^2)	1673.2 ± 1,368	4,111 ± 3397.2	−2.316	0.081	0.94
	HF power (ms^2)	1,219 ± 1282.8	1416.8 ± 804.3	−0.282	0.791	0.18
	LF/HF	2.298 ± 1.69	2.95 ± 1.432	−0.689	0.528	0.41
Crisis imagery	SDNN (ms)	57.62 ± 24.56	66.24 ± 13.45	−0.555	0.608	0.43
	RMSSD (ms)	38.66 ± 22.09	51.82 ± 9.28	−1.235	0.284	0.77
	LF power (ms^2)	1,287 ± 960.7	748 ± 368.4	0.979	0.382	0.74
	HF power (ms^2)	505.6 ± 477	871.4 ± 303.3	−1.678	0.168	0.91
	LF/HF	3.4 ± 2.3	1.014 ± 0.71	3.029	0.038*	1.4
Success imagery	SDNN (ms)	67.42 ± 31.64	83.38 ± 35.29	−0.622	0.567	0.47
	RMSSD (ms)	40.78 ± 21.83	62.2 ± 11.87	−1.597	0.185	1.21
	LF power (ms^2)	1218.2 ± 1042.8	1640.4 ± 1689.9	−0.473	0.66	0.3
	HF power (ms^2)	883.8 ± 990.9	1442.8 ± 632.4	−0.903	0.417	0.67
	LF/HF	1.933 ± 0.917	0.988 ± 0.572	2.843	0.046*	1.23

SDNN, standard deviation of the N-N; RMSSD, root mean square of Successive Differences; LF, low frequency; HF, high frequency. *$p < 0.05$.

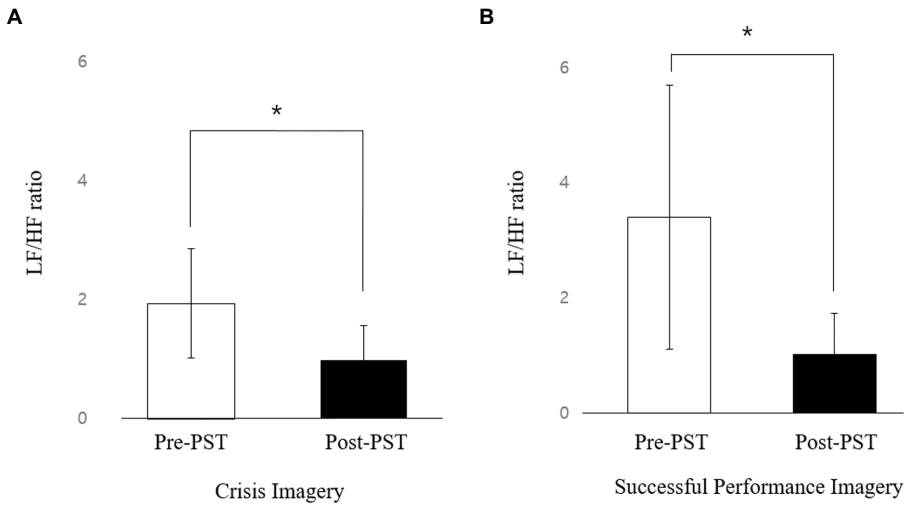

FIGURE 1
Changes in HRV LF/HF ratio in **(A)** crisis imagery condition and **(B)** successful performance imagery condition before and after PST. *$p<0.05$.

crisis imagery (t = −1.678, $p = 0.168$), and success imagery conditions (t = −0.903, $p = 0.417$) yielded no significant pre/post differences.

3.2. Questionnaires

Upon analyzing the psychological questionnaire responses, no significant difference was found as a function of PST in all sub-factors of the PSIAS: arousal regulation (t = −1.382, $p = 0.239$), attention/anxiety (t = −0.86, $p = 0.438$), achievement motivation (t = −1.191, $p = 0.299$), imagery control (t = −1.215, $p = 0.074$), and confidence (t = −2.408, $p = 0.074$). In addition, no significant difference was observed as a function of PST in all sub-factors of the SAS: somatic anxiety (t = 0.62, $p = 0.569$), worry (t = 1.857, $p = 0.137$), and concentration disruption (t = 0.00, $p = 1.00$). In the analyses of the IMI, a significant pre/post difference emerged in the sub-factor of perceived competence (t = −2.791, $p = 0.049$). Other sub-scales of the IMI indicated no significant pre/post differences: interest/enjoyment (t = −1.018, $p = 0.366$), effort/importance (t = −2.173, $p = 0.095$), and pressure/tension (t = 0.82, $p = 0.458$). The analysis of the TSCI, the measure of trait sports confidence, yielded a significant main effect of time (t = −2.792, $p = 0.049$). Particularly, higher post-PST scores on the measures of perceived competence and trait sport confidence were observed in contrast to the pre-PST scores (Table 3).

TABLE 3 Pre- and post-PST scores on psychological questionnaires.

Psychological questionnaires		Pre (mean±SD)	Post (mean±SD)	Paired *t*-test		
				t-value	*p*-value	Cohen's *d*
PSIAS	Imagery control	4.28 ± 1.24	4.84 ± 0.23	−1.215	0.291	0.62
	Attention/anxiety	3.16 ± 0.71	3.32 ± 1.02	−0.86	0.438	0.18
	Achievement motivation	3.96 ± 0.92	4.68 ± 0.53	−1.191	0.299	0.95
	Arousal regulation	3.56 ± 1.14	4.28 ± 0.22	−1.382	0.239	0.87
	Confidence	4.16 ± 0.73	5.02 ± 0.39	−2.408	0.074	1.46
IMI	Interest/enjoyment	3.50 ± 1.31	4.06 ± 0.75	−1.018	0.366	0.52
	Perceived competence	2.52 ± 0.95	3.36 ± 0.73	−2.791	0.049*	0.99
	Effort/importance	3.54 ± 0.87	4.36 ± 0.30	−2.173	0.095	1.26
	Pressure/tension	3.14 ± 1.03	2.90 ± 0.62	0.82	0.458	0.28
SAS	Somatic anxiety	2.78 ± 1.34	2.60 ± 0.70	0.62	0.569	0.16
	Worry	4.00 ± 0.64	3.48 ± 0.70	1.857	0.137	0.77
	Concentration disruption	2.64 ± 0.77	2.64 ± 0.59	0.00	1.00	0.0
TSCI		4.94 ± 1.17	6.60 ± 0.65	−2.792	0.049*	1.75

PSIAS, psychological skills inventory for archery and shooting; IMI, intrinsic motivation inventory; SAS, sports anxiety scale; TSCI, trait sports confidence inventory. *$p < 0.05$.

3.3. Interviews

We transcribed participant interviews conducted during the individual counseling sessions. The participants' description on their PST experience was as follows.

> "By participating in PST, I was able to clearly understand how the arousal level affects athletic performance. After training (PST), I was able to notice in real time when my arousal level deviated from an optimal state during competition or training. It was an amazing experience to find out that psychological sensitivity can be improved through training." (Participant A).

> "I liked the breathing relaxation training. It helped me the most to find my pace again when things did not go as I had expected when I became upset and out of control during shooting." (Participant D).

> "Breathing relaxation has become the most powerful weapon that helps me bring my awareness to the present (now) at the shooting range in a very short time without anyone knowing." (Participant B).

> "After entering high school, I played one or two matches and was disappointed to see that I had not changed at all from middle school. However, through this [PST] program, I regained my confidence and learned to think positively." (Participant A).

> "I fell behind and was excluded from the team event entries. Although I could not go out to the actual game, I was able to maintain my composure and confidence by creating various success scenarios and vividly rehearsing them repeatedly through imagery." (Participant C).

> "I always had a clear goal, which made me nervous at competitions. Through the goal setting session, I realized that up until now I had only focused on what I wanted to achieve (i.e., outcome goals). I was able to control my anxiety and tension as I became clear about what I actually needed to do to get what I wanted. I now know where to focus my attention during training or in competition." (Participant E).

> "As the players participated in the PST program, their emotional ups and downs decreased, and even if the results were not good, they showed a quick recovery from emotional stagnation." (Coach A).

4. Discussion

The PST aims to enhance performance in sports. However, it is difficult to assess the effectiveness of PST merely based on the competition results or records because of the complex interplay of multiple factors that affect performance. Therefore, the present study aimed to investigate the effects of PST psychophysiologically using HRV parameters in addition to a set of psychological questionnaires and participant interviews.

The findings of this study indicated that the 8-week PST program offered to junior air pistol shooters yielded significant improvement in perceived competence, which is a sub-factor of intrinsic motivation. Perceived competence is central to self-efficacy and it refers to an individual's cognitive perception of their capability to control an environment to succeed (Hughes et al., 2011). Research has demonstrated that PST content such as imagery can improve the motivation and perceived competence of sports performers who imagine themselves successfully implementing target motor skills, making optimal decisions, and coping well with crises during performance (Thelwell et al., 2006). As participant C mentioned in the interview, imagining a winning scenario during the time the athlete did not compete helped maintain self-efficacy. Furthermore, the PST

program presented in this study positively impacted the shooters' confidence, as suggested by the higher TSCI scores. These results are consistent with a previous study that reported positive improvements in trait self-confidence among adolescent volleyball players after 8 weeks (24 sessions) of the PST program (Heydari et al., 2018). Moreover, the shooters exhibited a strengthened belief in their ability to perform well during their individual counseling sessions.

Sports confidence is a fundamental component of successful performance in sports (Burton, 1988). Thus, enhancing the confidence of adolescent shooters participating in the PST program in the present study may potentially have a positive impact on actual performance.

Research has shown that confidence is positively correlated with coping skills and negatively correlated with anxiety (Cresswell and Hodge, 2004). The scales associated with anxiety and coping skills used in the current study did not change significantly after PST as indicated by the PSIAS and SAS scores. However, each psychological parameter exhibited a general pattern of improvement after 8 weeks of PST, in contrast to before. This implies that a statistically significant difference can occur after extending the PST session or incorporating a longer-term intervention. Such an expectation can be supported by a meta-analysis on the effects of PST in archers, which revealed that the effectiveness of PST depended on the training period, with interventions for 12 weeks or more yielding greater benefits than those for less than 12-week period (Kim et al., 2021).

Previous research suggests that participants found it challenging to experience perceivable changes through short-term interventions (Kim et al., 2021). Therefore, we adopted HRV parameters to track subtle changes that might have occurred within the participants through PST participation. Psychophysiological markers enable the objective observation of more sensitive changes that might not be reflected in self-report questionnaires. As a result, we found a significant decrease in the LF/HF ratio after PST in crisis imagery and successful performance imagery conditions upon analyzing the HRV frequency domain parameters.

The LF/HF ratio reflects the overall balance of the autonomic nervous system. Particularly, a higher LF/HF ratio demonstrates a relatively higher activity of the sympathetic nervous system or suppressed activity of the parasympathetic nervous system (Aubert et al., 2003). In this regard, the LF/HF ratio can act as a psychophysiological indicator of anxiety or arousal, with a higher LF/HF ratio indicating higher levels of anxiety or arousal (Bailey et al., 1996; Lee et al., 2010). These findings suggest that PST likely contributes to restoring the balance between the sympathetic and parasympathetic nervous systems. Consequently, PST facilitates regulating levels of anxiety and arousal during game situations that can be psychologically disturbing.

The relationship between the LF/HF ratio and anxiety has been widely reported in previous studies. Murray and Raedeke (2008) reported that LF/HF increased under pressure while performing a golf-putting task. A previous study examining the effects of preoperative music intervention on patients found that the self-rated anxiety score and LF/HF ratio decreased in the music intervention group (Wang et al., 2014). In another study by Wells et al. (2012), musicians who received slow breathing intervention exhibited a decreased LF/HF ratio and significant reductions in self-reported anxiety before a performance, in contrast to the controls. Particularly, this was attributed to increased parasympathetic nervous system activity, which could enhance competence in the participants' performance through the improved control of physiological arousal due to stress and anxiety before a musical performance. The HF power is closely related to activation of the parasympathetic nervous system, whereas the LF power reflects activation of the sympathetic nervous system associated with mental stress. Therefore, a high LF/HF ratio indicates relatively more activated sympathetic nervous system or suppressed parasympathetic nervous system activity. Conversely, in relaxed states with low arousal, the parasympathetic nervous system activity is dominant, and the LF/HF ratio decreases. A previous study which compared the changes in HRV of swimmers during competition and training reported decreased RMSSD and HF values and increased LF/HF ratio in anxiety-inducing competition situations (Blasquez et al., 2009). Consistent with previous studies, the current results show that the decrease in the LF/HF ratio after PST can reflect improved capabilities to regulate arousal and cope with pressure and anxiety.

The individual zone of optimal functioning (IZOF) model underscores that athletes have their own optimal zone of emotional experience for peak performance. Thus, deviation from the zone can impede performance (Hanin, 2000). The performance of an athlete can be negatively affected upon recognizing a crisis or success during a match as it is more likely to cause deviation from the optimal level of arousal. In circumstances where anxiety or tension is induced, various physical reactions such as an increase in heart rate, decrease in heart rate variability, and stiffness of muscles are commonly experienced in response to the activation of the sympathetic nervous system. However, the adaptive ability of the autonomic nervous system during emotional fluctuations, which is involuntarily regulated, significantly improved after the PST program in this study. Therefore, this demonstrates that the structured PST program adopted in this study (i.e., relaxed breathing, goal-setting, imagery, cognitive restructuring, and routine) could effectively improve the ability to regulate the sympathetic and parasympathetic nerves to cope better with performance-related stress, tension, or anxiety. For example, a study participant provided positive feedback during the individual counseling and underscored that breathing training in the PST program helped regulate arousal.

In this study, the time domain indices of HRV (i.e., SDNN and RMSSD) as well as the LF and HF powers of the frequency domain indices exhibited general improvement despite not producing any statistical significance. The increased values of these HRV indices measured during the relaxed breathing and sport-specific imagery conditions illustrate the possibility of improvements in the stress-coping function of the autonomic nervous system. Furthermore, Lim et al. (2019) reported increased SDNN and enhanced performance in a rifle shooter after a 40-week PST intervention, The SDNN results reflect responsiveness to mental stress regulated by the autonomic nervous system. While the RMSSD parameter, which describes short-term heart rate variance, reflects the integrity of vagus nerve-mediated autonomic control of the heart. Moreover, RMSSD has been correlated with increased stress (Orsila et al., 2008). Thus, the general increase in the SDNN and RMSSD parameters in the present study suggests that PST can positively influence developing capabilities to promote parasympathetic nerve activity in various stressful situations such as during a match, and to maintain composure.

To summarize the study findings, the perceived competence and trait sport confidence of junior pistol shooters who participated in the PST program for 8 weeks improved while the LF/HF ratio of HRV decreased significantly. These results suggest that PST may help athletes internalize psychological skills to cope with crises during games or in emotionally challenging situations by strengthening the responsiveness of the autonomic nervous system to stress. Furthermore, other parameters showed a general improvement pattern after PST participation. However, these findings were not statistically significant. Thus, this suggests that

implementing a PST program over a longer term or that is personalized to meet each athlete's specific needs might yield a larger effect.

This study had several limitations. First, it remains unclear whether PST participation has a positive effect on performance. Second, the subelements of the PST pro-gram that played a major (or minor) role in producing positive outcomes could not be identified. However, this study confirmed that a structured PST program can be beneficial, regardless of athletes' individual choices or preferences regarding the training content. Thus, this study has meaningful contributions as it quantitatively verified the effects of PST, which have been difficult to confirm directly through performance, using psychophysiological measures. Moreover, the findings of this study can serve as evidence and motivation for athletes to continuously invest time and effort in training and in practicing psychological skills and techniques.

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 provided for this study on human participants because this study was conducted on athletes in actual sports fields, and it was important to deliver the optimal PST to participating athletes according to their training and competition schedules, instead of waiting until IRB approval. Furthermore, it was an exploratory field study with a small number of samples and adopted non-invasive electrocardiogram measurements for a short period of time, where physical and psychological burdens on the participants were not critical. Since the study protocol was approved and funded by the Ministry of Education, we conducted the study after providing sufficient information to the participants in advance. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

GL: conceptualization, software, supervision, and project administration. GL and JR: methodology and formal analysis. JR: validation and data curation. GL and TK: writing—original draft preparation. TK: writing—review and editing and visualization. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

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Association between motor and math skills in preschool children with typical development: Systematic review

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Mathematics has been the subject in which many school-age children have revealed many difficulties. Research carried out in an attempt to understand the causes of failure in this area pointed to a positive association between mathematical performance and motor performance. Given the importance of math development in future school outcomes, knowing which specific motor components are most associated with math performance can help educators define better strategies for teaching mathematics. In this sense, the present systematic review study aimed to identify the components of motor skills most positively associated with mathematical performance in children with typical development who attend preschool. The PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was used in this study. The databases searched were ERIC, PubMED, SciELO, Scopus and Web of Science. A total of 2,909 articles were identified, of which 18 were included in this systematic review. The main results showed positive associations between fine motor skills, namely fine motor coordination and visuomotor integration, and mathematical performance. The math skill of numerical counting was the most associated with FMS. The main characteristics of the instruments used showed that the tasks of copying figures or drawings are the most used to assess visuomotor integration and the tasks of handling objects with pinch-like movements are the most used to assess fine motor coordination. Given the importance of mathematical performance in future school results, identifying early children with difficulties in fine motor skills will help educators to design better strategies for teaching mathematical skills. In this sense, the need to identify instruments to assess fine motor skills in preschool children with characteristics that facilitate their administration by the educator in the classroom context, i.e., requiring little administration time, not requiring much experience or training, the possibility of being administered to the group/class, few material resources, and the results can be easily interpreted, classified, and associated with mathematical performance.

KEYWORDS

children, preschool, motor skills, math skills, mathematical performance

1. Introduction

The relationship between motor and cognitive development goes back to Piaget's theory of cognitive development, highlighting the interconnection between individuals and the environment. The process of assimilation and, in particular, accommodation leads to the formation of new and more complex cognitive structures when the child interacts with the environment (Piaget and

Inhelder, 1966). According to Wallon (1941), children develop through movement, from action to representation, from physical to cognitive. Pelicier et al. (1996) stated that motor and psychological functions are the two fundamental elements of human behavior. Initially, they develop together, then they specialize and differentiate, although they remain subject to reciprocal interactions (Adolph and Franchak, 2017; Kim et al., 2018). The idea of "*learning to learn*" suggests that early learning is motor- system centered with brain systems involved in posture, grip, vision, and motor control, and as the child adapts to changes in cognitive and motor skills, he or she develops simultaneously (Adolph, 2005). Today, there is neurophysiological and neuroimaging evidence that the prefrontal cortex, cerebellum and connection structures are co-active in certain cognitive and motor tasks suggesting an interrelationship between motor and cognitive development (Diamond, 2000; Abe and Hanakawa, 2009).

Cross-sectional research has shown positive associations between motor skills and cognitive and academic assessments (Kantomaa et al., 2013; Lopes et al., 2013; Haapala et al., 2014; Diamond, 2015; Geertsen et al., 2016). Additionally, longitudinal studies carried out in typically developing populations have found a relationship between motor development and cognitive development throughout the life cycle. Motor skills acquired at a very early age may be related to cognitive skills during childhood (Michel et al., 2016), adolescence (Cantell et al., 2003), and even adulthood (Kuh et al., 2006). Recent studies have highlighted that motor skills influence academic performance in the early years (Carson et al., 2016; Alvarez-Bueno et al., 2017; Zeng et al., 2017; Macdonald et al., 2018; De Waal, 2019; Duncan et al., 2019; Haapala et al., 2019; Malambo et al., 2022), and are described as one of the criteria for school readiness (Department for Education, 2020; Jones et al., 2021). For this reason, an assessment of motor skills at an early age can help to identify children who are likely to perform poorly in academic skills in advance (Roebers et al., 2014; Cameron et al., 2016; Pitchford et al., 2016; Schmidt et al., 2017; Goodway et al., 2019).

1.1. Motor skills

The term fundamental motor skill was defined by Wickstrom (1977) as a basic motor activity for more advanced and highly specific activities such as running, jumping, and throwing, among others. Currently, the term fundamental motor skill reflects various terminologies that have been used in the literature such as motor proficiency, motor performance, fundamental movement ability, fundamental motor skill, motor skill and motor competence (Robinson et al., 2015).

Various terms have been used to describe fundamental motor skills, such as: gross motor skills (Pang and Fong, 2009; Mostafavi et al., 2013), fundamental motor patterns (Barnett et al., 2012), and fundamental movement skills (Staples and Reid, 2010; Barnett et al., 2015). Similarly, various terminologies have been commonly used to describe fine motor skills, such as: fine motor proficiency, fine motor accuracy, fine motor integration, manual dexterity, or fine motor coordination (Bruininks and Bruininks, 2005) or performance motor skills (Sortwell et al., 2022).

In view of the numerous terminologies found in the literature, the present systematic review is based on the terminologies used in the reviews published by Macdonald et al. (2018), Donnelly et al. (2016) and van der Fels et al. (2015), due to the fact that they present similar objectives. These reviews used the term Motor Skills and the underlying domains as gross motor skills and fine motor skills.

Motor skills (MS) refer to efficient and effective actions resulting from a learning process (Magill, 1984). According to movement control and precision, they are divided into two categories, gross motor skills (GMS) and fine motor skills (FMS). These two categories of motor skills are used in research to analyze the relationship between cognitive and motor development (Grissmer et al., 2010; Gentier et al., 2013; Raisbeck and Diekfuss, 2015; Van der Fels et al., 2015; Oberer et al., 2017; Macdonald et al., 2018; Haywood and Getchell, 2019).

GMS primarily use movements produced by large muscle groups. They include motor skills that imply movement of the body in space, such as walking, running, jumping, sliding, and postural skills, which refer to the ability to keep a controlled position or posture during a specific task or activity (they can be dynamic or static) and manipulative skills used to control objects in actions such as grabbing, hitting, absorbing, lifting, etc., with hands, feet or using other objects for that purpose (Ulrich, 2000; Grissmer et al., 2010; Lopes et al., 2013; D'Hondt et al., 2014; Magistro et al., 2015; Rudd et al., 2015; Chang and Gu, 2018; Haywood and Getchell, 2019). On the other hand, FMS can be defined as movements produced by small muscle groups that involve activities with great precision, implying two distinct capabilities, motor coordination, and visual integration, as well as the integration of both (Carlson et al., 2013). In this context, different types of FMS can be identified depending on the capabilities involved (Kimmel and Ratliff-Schaub, 2011; Carlson et al., 2013). A type of FMS consists of fine motor coordination (FMC), which refers to movements that involve oculus-manual coordination (eye-hand), manual dexterity, motor sequencing, and speed and precision, such as tracing, touching with fingers, building with Legos/blocks, moving coins from one place to another or inserting them into a slot, etc., which can also be called non-graphomotor skills (Davis and Matthews, 2010; Suggate et al., 2018).

Another type of FMS consists of visual motor integration or visuomotor integration (VMI) and spatial or visuospatial integration (VSI), which refers to the organization of small muscle movements of the hand and fingers through the processing of visual and spatial stimuli, more based on synchronized hand-eye movements (Sortor and Kulp, 2003; Carlson et al., 2013; Fuhs et al., 2014; Kim et al., 2018), typically writing, drawing, copying shapes, letters, or other stimuli (Beery and Buktenica, 1997; Grissmer et al., 2010; Roebers et al., 2014; Oberer et al., 2017) that can be called graphomotor skills (Davis and Matthews, 2010; Suggate et al., 2018). Figure 1 summarizes the categories of motor skills.

1.2. Mathematical performance

The performance of academic skills preferentially values two curricular areas, literacy and mathematics performance (Fernandes et al., 2016; Ribner et al., 2017). These two areas are considered prerequisites for performance in other subjects and, consequently, for academic success (Organization for Economic Cooperation and Development (OECD), 2016). However, mathematics plays an important role in the school curriculum and its development. In a modern, technological society, it is seen as a fundamental cognitive attribute, where successful early learning provides not only a framework for later learning (Duncan et al., 2007) but is also an indicator of future academic and professional success (Parsons and Bynner, 2005).

Mathematics is learned by children before school through numbers and quantities (Blair, 2002; McWayne et al., 2004) and the informal knowledge they acquire is often referred to as "basic numerical skills," being a precondition for mathematical reasoning (Gersten et al., 2005; Jordan et al., 2006). Studies have shown that math skills in preschool

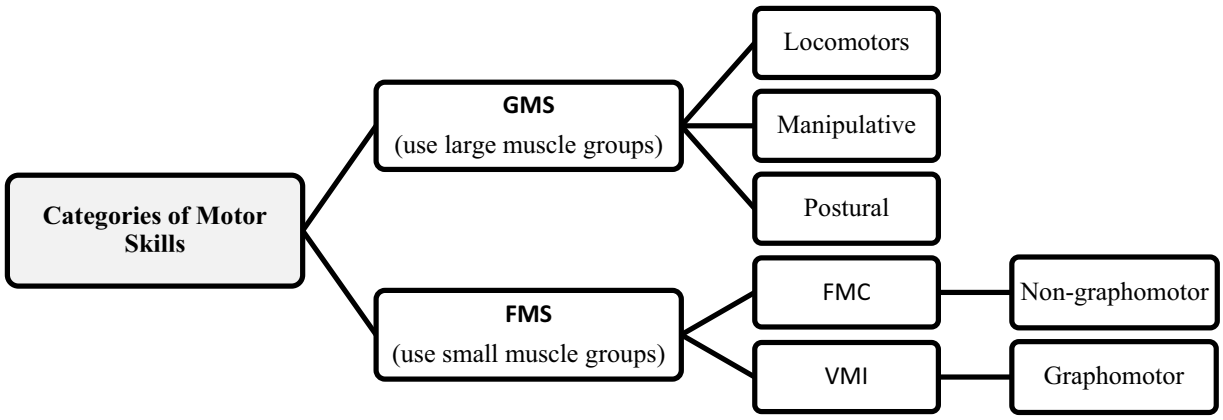

FIGURE 1
Summary of motor skills categories (Author's figure).

education predict performance in reading, math, and science through grade 8 (children between 13 and 14 years old; Claesens and Engel, 2013).

The math skills children acquire in preschool education are important for developing a conceptual understanding of mathematics (Jordan et al., 2009; Siegler et al., 2012), as well as confidence in the ability to engage in activities that support analytical thinking, problem solving and reasoning and argumentation skills (Clements et al., 2004). However, teaching mathematics in preschool education must be related to children's day-to-day interests, such as playing or exploring everyday situations (Silva et al., 2016).

It is recognized that pre-school children enjoy activities that develop their math skills (Ginsburg et al., 2006). However, most early childhood educators typically place greater emphasis on children's social–emotional and literacy development and less attention to mathematics (National Research Council, 2009). Many early childhood educators avoid teaching mathematics because of their own negative experiences with it (Ginsburg et al., 2006; Clements and Sarama, 2007).

Fundamental learning for the development of mathematical competences in preschool education consists of two main areas: Numbers (1) and Geometry and Measurement (2). Each of these areas consists of different skills. The area of numbers is subdivided into the core of numbers (counting, cardinality, and identification of numbers), operations (addition and subtraction) and relations (comparing). Regarding the area of geometry and measurement, geometry consists of shapes and space, and measurements of length, area, and volume (National Research Council, 2009; Figure 2).

Numbers are abstractions that apply to a wide range of real and imaginary situations. These do not exist in isolation, but constitute a system of relations and operations by which they can be compared, added, subtracted, multiplied, and divided. These relationships apply to a wide variety of problems (National Research Council, 2009). On the other hand, geometry and measurement provide systems for describing, representing, and understanding the world. Geometry is the study of shapes and spaces (two-dimensional-2-D and three-dimensional – 3-D). Measurement is about determining the size of object shapes (National Research Council, 2009). In this sense, preschool children need to learn the following math skills (National Research Council, 2009):

Core of numbers (*cardinality, counting, and identification*);

Cardinality – Children learn the concept of cardinality when they understand that adding an object means counting to the next number (Sarnecka and Carey, 2008).

Counting – Counting means listing the count numbers in order, usually starting at 1. It is a way of making a 1 to 1 correspondence between each object (Wynn, 1992).

Number Identification – It is the ability to associate a written number (e.g., 5) with a verbal word (e.g., five; Jordan et al., 2009).

Relationships (*comparing*);

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Comparing – represents the comparison of quantities of groups of objects using words such as "more/bigger," "less/smaller" and "equal." A basic way to compare two quantities of objects is by direct correspondence. If a child has a noticeably larger set of black beads compared to a set of white beads, the child identifies which group has the larger amount of beads. Thus, these skills can be developed separately from other basic math skills, such as counting and cardinality and number identification, because it is not necessary to know the exact number of objects in each group to successfully compare two groups (Traverso et al., 2021).

Operations (*addition and subtraction*);

Addition and subtraction – refer to basic arithmetic skills such as adding and subtracting and are used to relate quantities. Children are only prepared to develop these skills when they understand the concepts of cardinality and counting. These skills prepare children to develop more complex arithmetic skills such as multiplication and division (Barth et al., 2008; Canobi and Bethune, 2008).

Geometry (*shapes and space*).

Shapes – Shape is the basic way children learn to name objects (Jones and Smith, 2002). Children have an innate and implicit ability to recognize and match shapes (Anderson, 2000).

Space – Space includes two main skills: spatial orientation and spatial visualization of images. Spatial orientation involves knowing where you are and how to move around in the world (Gelman and Williams, 1997). Children learn words such as "beside" and "between." Later, they learn words referring to frames of reference, such as "in front of," "behind." The words "left" and "right" are learned much later, and are a source of confusion for several years (Gopnik and Meltzoff, 1986). In these early years, children can also learn to analyze a route through a space (Wang and Spelke, 2002). Spatial visualization of images is about understanding and performing imagined movements of 2-D and 3-D objects. This requires being able to create a mental image and manipulate it through a close relationship between these two cognitive abilities.

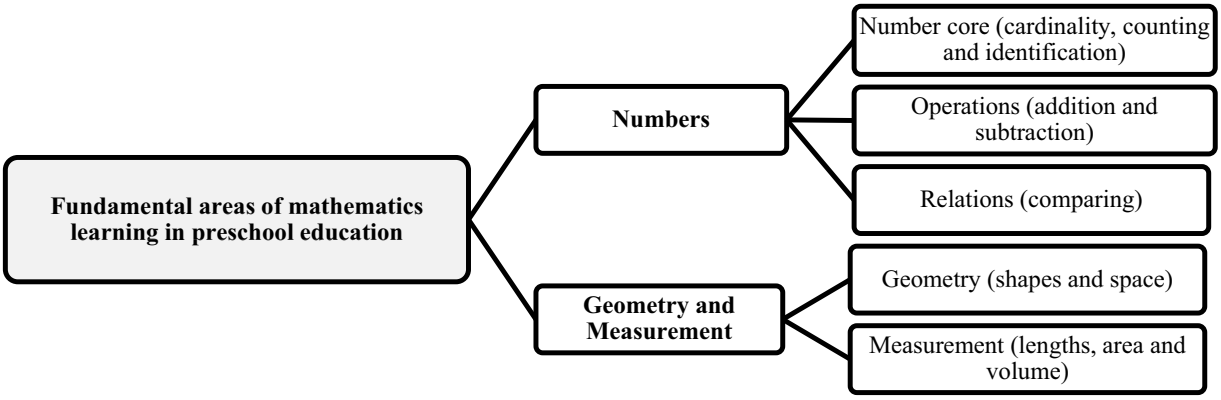

FIGURE 2
Summary of fundamental areas of mathematics learning in preschool education according to the National Research Council, 2009 (Author's figure).

Spatial visualization of images has been positively associated with the construction and composition of shapes (Sarama et al., 1996).

Measurement (*length, area, and volume*).

Length Measurement – quantifies the distance between points in object or space.

Area Measurement – is a quantity of 2-D surface area that is contained within a boundary.

Volume Measurement – volume introduces even more complexity by the addition of a third dimension (3-D), presenting a significant challenge to students' spatial structuring (Curry and Outhred, 2005).

One way to more formally assess children's understanding of measurements is through comparison tasks (Mullet and Paques, 1991).

1.3. Relationship between motor and math skills

The literature has pointed out a positive association between mathematics and motor skills (Macdonald et al., 2018) and, according to the theory of "*Embodied Cognition*" (Embedded Cognition), cognition emerges from the "*coupling*" (embodied relationship) of the individual with the physical and social context as a result of sensorimotor activity (Smith, 2005). According to this paradigm, body movement causes changes in neural networks, stimulating significant gains in cognition. Within this paradigm, several investigations have highlighted the importance of movement in cognition, particularly in the performance of math skills such as abstract cognitive representations in general, and in the improvement of basic numerical representations in particular (Link et al., 2013). As proposed by Fischer et al. (2018), numbers are embodied concepts and not abstractions dissociated from sensory experiences. In addition, the theory assumes that certain cognitive and motor areas of the brain are activated simultaneously when solving mathematical problems (Fischer and Brugger, 2011).

Much research has been produced in an attempt to demonstrate the association between MH and cognition, but few have considered different categories of motor skills (gross/fine) and different categories of cognitive skills (executive functions/academic success in reading and mathematics; Oberer et al., 2017). Depending on the different categories of variables studied, the results differ and it is not possible to reach conclusive data (Magistro et al., 2015; Veldman et al., 2019). Furthermore, each study analyzed different motor skills and academics, performed them in different ways, or evaluated populations with different characteristics. All these aspects contribute to a disparity of results in this area (Magistro et al., 2015; Veldman et al., 2019). It is, therefore, a complex area of study that does not allow consensual conclusions (Escolano-Pérez et al., 2020). In this sense, it is considered necessary to study the associations between the different categories of specific motor skills and academic skills, in order to contribute to the success of children's learning.

1.4. Relevance of the study

The subject of mathematics was selected for this study for the following reasons: first, because it is a "universal language" (across all countries); second, because it is the subject in which many school-age children have difficulties in learning, a problem with incidence ranging from 3% to 7% (Shalev et al., 2005; Swanson et al., 2009; Devine et al., 2013, 2018). These difficulties occur more than expected (Koponen et al., 2018; Willcutt et al., 2019) and are already observed at preschool age (Desoete et al., 2012; Devine et al., 2018); third, in light of the priority for children to develop basic numeracy skills upon entry to grade 1 (Rimm-Kaufman et al., 2000; Verdine et al., 2014; Duran et al., 2018; Cameron et al., 2019; Nesbitt et al., 2019; Escolano-Pérez et al., 2020); fourth, it is a strong predictor of future academic success (Parsons and Bynner, 2005; Carr and Alexeev, 2011; Fuchs et al., 2016).

Considering the importance of mathematics in future school results, knowing which motor skills can contribute to improving mathematical performance will help educators to select and program more appropriate strategies for teaching and learning math skills.

In this sense, the present systematic review study aims to identify in children with typical development who attend preschool education, the different categories of motor skills that are associated with math skills and the instruments used in investigations carried out with this objective.

It was hypothesized that motor skills positively influence mathematical performance.

2. Materials and methods

2.1. Identification of studies

A search was carried out in electronic databases, by two reviewers (PF, PF), according to the PRISMA protocol (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) to identify relevant studies

(Moher et al., 2009). The databases searched were ERIC, PubMED, SciELO, Scopus, and Web of Science. The research was conducted on January 15, 2022 and the period was restricted to the last 10 years. The research made no restrictions regarding language. Although the last 5 or 10 years may be well-defined periods for research (Sampaio and Mancini, 2007; Donato and Donato, 2019), they may not, however, be the most appropriate. Thus, we conducted a search in the databases used in this study on systematic reviews published on the subject under study and found that the vast majority were published from 2012 onwards. Thus, the last 10 years were chosen instead of the last 5 years. EndNote was the program used to manage bibliographic references. Keywords were used to identify the relevant literature according to the objective of the study. The research was performed according to the abstract of the articles and the phrase used to detect them in all databases was: ((motor AND (motor AND (proficiency OR competency OR skill* OR development OR ability OR performance OR gross OR fine)) AND ("academic performance" OR "academic achievement" OR "academic grids" OR math* OR numeracy) AND (child* OR preschool*)).

2.2. Selection of studies

After removing duplicates, the titles and abstracts of the remaining studies were read, by two reviewers independently (PF, PF), and selected with reference to the predefined inclusion and exclusion criteria to assess their potential eligibility for this systematic review. Studies in which the abstract clearly indicated that they would be ineligible for inclusion were immediately eliminated, however, those in which there was some doubt as to their eligibility were kept.

Subsequently, the full texts of these articles were obtained to assess eligibility for inclusion in this review by the two reviewers (PF, PF) and in case of doubt the studies were reevaluated together, following inclusion and exclusion criteria. This research followed the PICOS criteria (population, intervention, comparison, outcome, study; Moher et al., 2009): P, preschool children with typical development; intervention, motor skills diagnosis; C, relationship between motor skills and mathematics; O, evidence of the influence of motor skills on mathematical performance; S, cross-sectional or longitudinal studies, with or without intervention, in any language and in any publication format (articles and or papers).

a. Inclusion criteria:

1. The study population should include typically developing children attending preschool education, between the ages of 2.5 and 7 years. Atypical development is defined as the development of children who exhibit early delays, deviations, or disabilities below the desired development for the same age group (Jones et al., 2014; D'Souza and Karmiloff-Smith, 2017; Johnson et al., 2021).
2. Studies should include an association between mathematical performance and at least one specific component of motor skills (GMS and FMS; Grissmer et al., 2010; Gentier et al., 2013; Raisbeck and Diekfuss, 2015; Van der Fels et al., 2015; Oberer et al., 2017; Haywood and Getchell, 2019);
3. The studies should be primary observational studies (longitudinal and transversal);
4. Objective measures should be used to assess the specific components of motor skills and mathematics;
5. Appropriate statistical analyses to report associations should include correlations.

b. Exclusion criteria:

1. Studies with populations of children diagnosed with mental illness, neurological disorders (learning difficulties, motor coordination disorder, attention deficit hyperactivity disorder, autism spectrum, and cerebral palsy), and premature children. Studies with premature children who did not develop cerebral palsy were excluded, because among the most frequent problems are those associated with GMS and FMS (de Kieviet et al., 2009; Williams et al., 2010), in which they have been shown to be a negative influence on their academic performance (McHale and Cermak, 1992; Feder et al., 2005; Feder and Majnemer, 2007; Edwards et al., 2011).
2. Secondary studies (non-systematic and systematic reviews, with or without meta-analysis);
3. Studies that did not show associations between math skills and at least one specific component of motor skills (Bruininks and Bruininks, 2005; Carlson et al., 2013);
4. Studies that did not present the results aim to assess the specific components of motor skills and mathematics;
5. Studies that did not include in statistical analyses the correlations between at least one specific component of motor skills and mathematics.

After reading the articles in full, some were excluded because they did not meet all the inclusion criteria. Eligible studies were kept and included for methodological and subsequent quality assessment, data extraction, discussion, and conclusions.

An additional search was conducted in the references of the articles included in the review in order to add relevant articles. After the search, no referenced articles met all the criteria for inclusion in this review.

2.3. Critical assessment of methodological quality

The methodological quality of the studies was assessed by two independent reviewers (EC and IM). In case of disagreement, the studies were jointly reassessed until a consensus was reached regarding the final score.

The Methodological Quality Checklist for studies based on Observational Methodology (MQCOM), intended for studies using observational methodology, was used to assess the methodological quality of the studies. This instrument was firstly designed by Chacón-Moscoso et al. (2018) that determined the primary criteria/dimensions to take into account when reporting research using observational methods and developed a list of metrics to quantify them (Anguera and Hernández-Mendo, 2015; Portell et al., 2015; Chacón-Moscoso et al., 2016). Recently this instrument was reduced to 16 questions (Chacón-Moscoso et al., 2019), allowing to identify the main methodological quality items needed to conduct studies based on observational methodology and offer the results as a useful tool for authors conducting studies and reviewers making publication decisions.

The MQCOM is composed of 16 items divided into 11 criteria/dimensions: Criterion 1 – Delimitation of objectives is composed of 3 items (Item 1. Reference to observational methodology, specifying

whether observation is direct or indirect; Item 2. Delimitation of study objectives; Item 3. Theoretical framework referenced). Criterion/dimension 2 – Observational design, consists of 3 items [Item 4. Observation unit criteria (idiographic: study units are formed by one or more participants if there is a stable link between them; nomothetic: two or more study units); Item 5. Temporal criteria (punctual: one or two observation sessions; follow-up: more than two observation sessions); Item 6. Dimensionality criteria (one-dimensional: one level of response; multidimensional: two or more levels of response)]; Criterion/dimension 3 – Participants/observation units, consists of 1 item [Item 7. Clear specification of inclusion and exclusion criteria for observation units (reasons why some units were chosen in the study and others were not)]. Criterion/dimension 4 – Observation instruments, consists of 2 items [Item 8. Adequacy of the observation instrument (combination of field format with category system, field format, category system, or scale of estimation); Item 9. Codification manual with definition of the categories/behaviors and specification of dimensions (in multidimensional designs)]; Criterion/dimension 5 – Software use, consists of 1 item [Item 10. Software used to register data (SDIS-GSEQ v. 4.2.1./GSEQ 5, LINCE, MATCH VISION STUDIO, Transana, other: specify), control data quality (SDIS-GSEQ v. 4.2.1./GSEQ 5, LINCE, HOISAN, GT, SAS, other: specify)], and analyze data (SDIS-GSEQ, HOISAN, THEME v. 6, R, SAS, other: specify); Criterion/dimension 6 – Data, consists of 1 item [Item 11. Specification of data type as sequential/concurrent (sequential data: behaviors that cannot overlap and belong to a single dimension; concurrent data: behaviors that can co-occur and belong to several dimensions) and event-based/time-based (event-based: the primary parameter used in the record is order of events; time-based: the primary parameter is duration)]; Criterion/dimension 7 – Specification of parameters, consists of 1 item (Item 12. Type of parameters according to given use); Criterion/dimension 8 – Observational sampling, consists of 1 item (Item 13. Delimitation of sessions: clear establishment of criteria (temporal, behavioral, or mixed) for the beginning and the end of sessions within the observation period and of criteria for acceptance of sessions: between-sessions constancy, within-sessions constancy, or temporary disruptions); O Criterion/dimension 9 – Data quality control, consists of 1 item [Item 14. Between-observer reliability (agreement between the records of different observers)/within-observer reliability (agreement between the records of the same observer at two time points)]; Criterion/dimension 10 – Data analysis, consists of 1 item (Item 15. Type of data analysis performed); Criterion/dimension 11 – Interpretation of results, consists of 1 item (Item 16. In the discussion section).

According to Chacón-Moscoso et al. (2019) items are rated between zero and one. The value zero represents, does not comply; The value one represents, meets the criteria; The value 0.5 represents, partially complies. Items 3 and 15 are exceptions, as they still have different intermediate quotations between zero and one (0, 0.33, 0.67, and 1). Item 11 has a rating of nine, not applicable. The minimum value of the MQCOM is zero points and the maximum is 16 points (Chacón-Moscoso et al., 2019).

2.4. Data extraction

Data were independently extracted by two reviewers (PF, PF) and cross-checked, and controversial issues were discussed based on the original text to determine the final outcome. The extracted information included study characteristics: author, year, type of study and country where the study was carried out; main characteristics of the sample (number, sex and age); aim of the study, main results and conclusions; specific components of motor skills associated with different mathematical competences; instruments used to assess motor skills and mathematical competences.

Considering the methodological heterogeneity among the studies and instruments for the collection of data related to motor skills and mathematics and quality of the studies, it was not possible to carry out a meta-analysis.

3. Results

3.1. Included studies

The total search result in the databases produced 2,909 studies (PubMed: $n = 860$; Scopus: $n = 1{,}004$; Web of Science: $n = 778$; SciELO: $n = 35$; ERIC: $n = 232$), of which 965 were automatically excluded because they were duplicates and, after reading the title and abstract, 1,776 studies were excluded, thus resulting in a total of 168 studies potentially suitable studies. After reading these studies in full, 150 were excluded because they did not meet all inclusion criteria and, so, only 18 were included. After selecting the studies included for the review, a manual search of their bibliographic references was performed, from which no study was obtained, either because they did not meet all the eligibility criteria or because they were already included in the selection. The flowchart according to PRISMA methodology is shown in Figure 3.

Of the 18 studies included in this review, the following procedures were performed: Methodological quality assessment (3.2); Analysis of the main characteristics of the studies (3.3); Association between motor skills and the performance of mathematical competences (3.3); Identification of the instruments used in the studies to assess motor skills and mathematical performance (3.4).

3.2. Methodological quality assessment

With regard to the studies' rating, observed through MQCOM, on a scale from 0 to 16 points, the studies with the lowest rating obtained 12 points (Suggate et al., 2017; Fischer et al., 2018, 2020; Clark et al., 2021) and the highest rating was obtained by the study of Escolano-Pérez et al. (2020) (Table 1). Regarding the methodological characteristics, all 18 studies make reference to the methodology used (item 1), use observation units with criteria (item 4), fit the observation instruments to the study (item 8), the data and parameters are specified in the study (items 11 and 12), and all studies indicate having performed some inferential analysis to analyze the data. It is noteworthy that all studies perform a good interpretation of the results in the discussion section (item 16), except for the studies of Brock et al. (2018) and Osorio-Valencia et al. (2017) which partially met this criterion. Among all the studies, only one does not partially meet the theoretical framework (item 4) nor does it specify the coding manual with definition of the categories/behaviors and specification of the dimensions (Osorio-Valencia et al., 2017). The major limitation of the studies was the non-use of software for data collection, since only the study by Escolano-Pérez et al. (2020) met this criterion and the study by Clark et al. (2021) partially met it. Probably the design of the studies did not require the use of specific software for data collection, analysis, and interpretation.

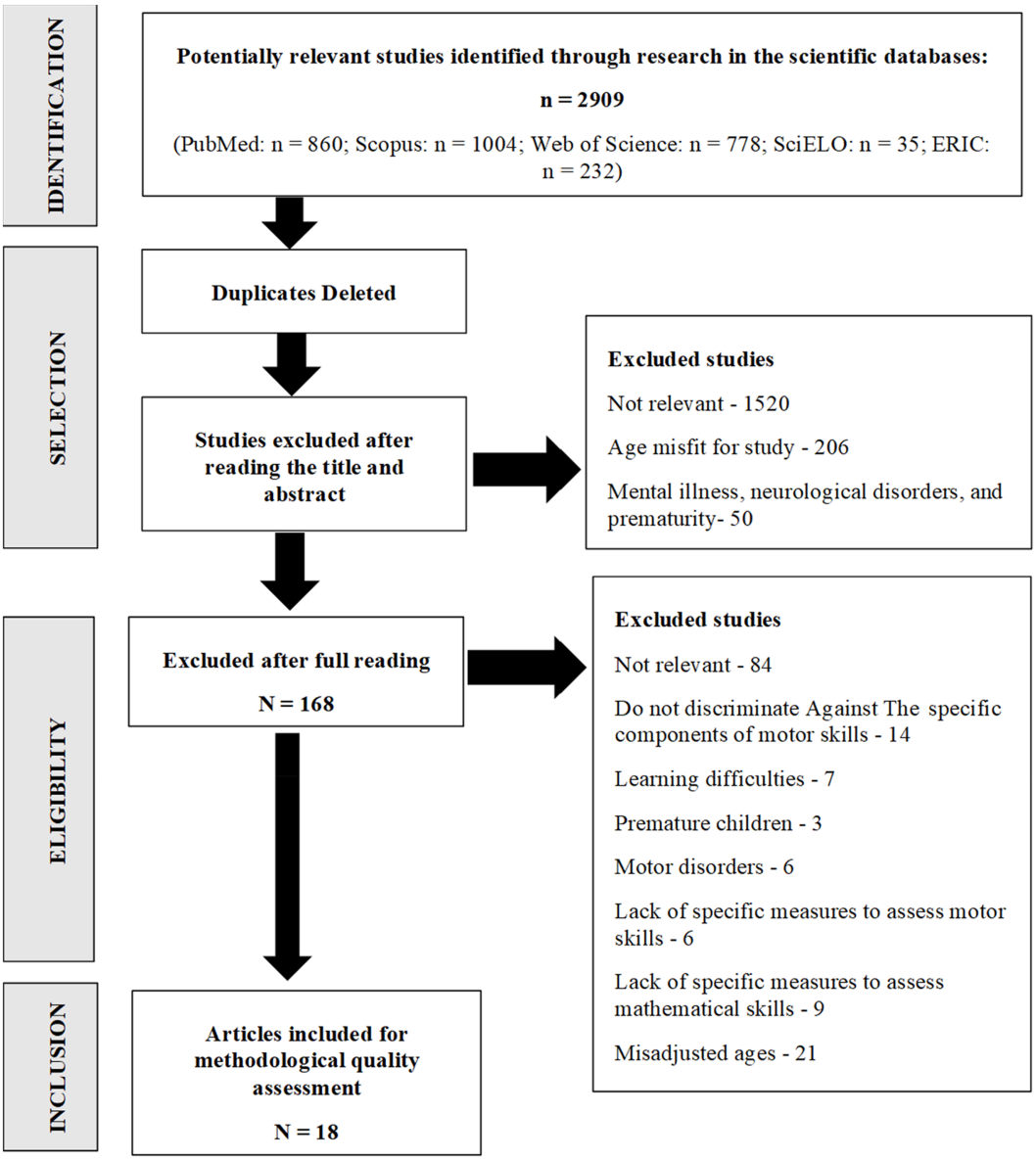

FIGURE 3
Flowchart of research processes for the inclusion of studies (PRISMA).

3.3. Characteristics of studies

The 18 studies included in this review were observational studies, 11 (61%) longitudinal and 7 (39%) transversals, which identified associations between motor skills and mathematical performance, using validated and reliable instruments for this purpose, in typically-developed children of both sexes, who attended preschool education. Regarding their country of origin, the majority of studies, 10 (56%), were conducted in the United States (Dinehart and Manfra, 2013; Verdine et al., 2014; Manfra et al., 2017; Brock et al., 2018; Duran et al., 2018; Kim et al., 2018; Cameron et al., 2019; Nesbitt et al., 2019; Greenburg et al., 2020; Clark et al., 2021), followed by three from Germany (17%; Suggate et al., 2017; Fischer et al., 2018, 2020). The remaining five studies were carried out in different countries, namely Singapore (Khng and Ng, 2021), Spain (Escolano-Pérez et al., 2020), South Africa (De Waal, 2019), Mexico (Osorio-Valencia et al., 2017), and Northeast Pacific (Becker et al., 2014; Table 2).

Regarding the sample size, the studies presented a minimum of 33 (Clark et al., 2021) and a maximum of 34.491 (Greenburg et al., 2020), with a total of 43.447 participants. All studies included children of both sexes. Regarding teaching frequency, most studies, 12 (67%), exclusively included children from preschool education, seven transversals (Becker et al., 2014; Suggate et al., 2017; Fischer et al., 2018; De Waal, 2019; Fischer et al., 2020; Clark et al., 2021; Khng and Ng, 2021) and five longitudinal (Verdine et al., 2014; Osorio-Valencia et al., 2017; Kim et al., 2018; Cameron et al., 2019; Escolano-Pérez et al., 2020). The remaining six studies (33%) were longitudinal and included children from preschool education and later years (Dinehart and Manfra, 2013; Manfra et al., 2017; Brock et al., 2018; Duran et al., 2018; Nesbitt et al., 2019; Greenburg et al., 2020; Table 2). Regarding age, in studies that included only preschool education, children were aged between 2.7 (Fischer et al., 2018) and 6.8 (Kim et al., 2018), and in studies that involved children from preschool education and beyond, the minimum age was 4 years and

TABLE 1 Methodological characteristics observed using the Methodological Quality Checklist for studies based on Observational Methodology (MQCOM).

Author and year	Item																Total
	Reference to observational methodology	Delimitation of study objectives	Theoretical framework referenced	Observation unit criteria	Temporal criteria	Dimensionality criteria	Inclusion/ exclusion criteria	Adequacy of the observation instrument	Coding manual	Software usage	Data type specification	Parameters specification	Session delimitation	Inter-observer reliability	Type of data analysis	Interpretation of results in the discussion	
Clark et al. (2021)	1	0.5	1	1	0	1	0	1	1	0.5	1	1	1	0	1	1	12
Khng and Ng (2021)	1	0.5	1	1	1	1	0.5	1	1	0	1	1	1	0	1	1	13
Escolano-Pérez et al. (2020)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
Fischer et al. (2020)	1	0.5	1	1	0.5	1	0.5	1	1	0	1	1	0.5	0	1	1	12
Greenburg et al. (2020)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	15
Cameron et al. (2019)	1	1	1	1	1	1	0.5	1	1	0	1	1	1	1	1	1	14.5
de Waal (2019)	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	14
Nesbitt et al. (2019)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	15
Brock et al. (2018)	1	1	1	1	0.5	0.5	0.5	1	1	0	1	1	0.5	1	1	0.5	12.5
Duran et al. (2018)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	15
Fischer et al. (2018)	1	1	1	1	0	1	0.5	1	1	0	1	1	0.5	0	1	1	12
Kim et al. (2018)	1	1	1	1	1	1	0.5	1	1	0	1	1	1	1	1	1	14.5
Manfra et al. (2017)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	15
Osorio-Valencia et al. (2017)	1	0.5	0.67	1	0.5	0.5	1	1	0.5	0	1	1	1	1	1	0.5	12.17
Suggate et al. (2017)	1	0.5	1	1	0.5	1	0.5	1	1	0	1	1	0.5	0	1	1	12
Becker et al. (2014)	1	1	1	1	0.5	1	0.5	1	1	0	1	1	0.5	0	1	1	12.5
Verdine et al. (2014)	1	1	1	1	0.5	1	0.5	1	1	0	1	1	0.5	1	1	1	13.5
Dinehart and Manfra (2013)	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	15
Total	18	15.5	17.7	18	13	17	12.5	18	17.5	1.5	18	18	15	12	18	17	

1 = meets the criteria; 0.5 = partially complies; 0 = does not comply.

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TABLE 2 Characteristics of studies that investigated the relationship between motor skills and mathematic performance in children who attended the preschool education with typical development.

Author country type of study	*N*	Sex	Age in years (mean)	Aim of the study	Study results and conclusions
Clark et al. (2021) United States Transverse	33	D	4–5 (4.66)	To investigate the association between fractional tasks and performance in fine motor skills and the use of gesture while counting	Performance in the**FMC** significantly predicts fractional reasoning tasks ($R2 = 0.258$; $p = 0.003$)
Khng and Ng (2021) Singapore Transverse	1.248	M 614 F 631	(4.78)	Examines the interaction between FMS and executive function in the simultaneous prediction of mathematics, reading and spelling in early kindergarten	**VMI** significantly predicted math performance ($r = 0.637$; $p < 0.01$). Identifying VMI difficulties early in kindergarten may be important for diagnosing learning difficulties in mathematics
Escolano-Pérez et al. (2020) Spain Longitudinal (1 year)	38	M 12 F 16	5–6 (5.72)	Assess in the last year of preschool the specific components of GMS and FMS and 1 year later and link to academic skills (literacy and math)	Of all the specific motor skills (GMS and FMS), only**VMI** predicts later math performance ($\beta = 0.476$; $p = 0.002$; R2 = 0.227; R2aj = 0.205; $p = 0.003$). Early assessment of VMI is critical to identify academic performance
Fischer et al. (2020) Germany Transverse	80	M 40 F 40	3.1–6.3 (4.80)	Verify that the FMS (FMC and IVM) are associated with finger-based numerical representations (ordinal and cardinal)	Only the**FMC** was related to numerical representations based on the fingers (ordinal: $r = 0.751$; $p < 0.01$; cardinal: $r = 0.781$; $p < 0.01$). Finger counting habits are a predictor of mathematical performance
Greenburg et al. (2020) United States Longitudinal (4 years)	34.491	D	(4.68)	Examine the importance of FMS in preschool for later school performance (3rd, 4th and 5th grade)	Both VSI and FMC were significantly associated with mathematics performance in later years (VSI: $0.15 > \beta > 0.10$; $p < 0.01$; FMC: $0.06 > \beta > 0.05$; $p < 0.01$).**VSI** and**FMC** are predictors of later school mathematics performance
Cameron et al. (2019) United States Longitudinal (1 year)	555	D	(T1 5.28 T2 6.28)	Examine associations between cognitive and academic skills: executive function, VMI, mathematics, and letter and word knowledge	Children with better**VMI** showed better results in solving applied problems (T1: $r = 0.48$; $p < 0.001$; T2: $r = 0.48$; $p < 0.001$), contributing to early learning of mathematical problems
De Waal (2019) South Africa Transverse	69	M 38 F 31	5–6 (6.1)	Determine the correlation between motor skills and academic performance	Of the GMS,**balance** (dynamic and static) correlated moderately and significantly with math performance ($0.46 > r > 0.23$; $p < 0.05$). Children should be exposed to activities that include balance to improve math performance
Nesbitt et al. (2019) United States Longitudinal (2 years)	1.138	M 620 F 518	(T1 4.5 T4 6.4)	To examine the longitudinal associations between VMI, executive function, and mathematics performance	The increase in math performance over time is a product of the influence of executive functions and**VMI** (T1: $r = 0.29$; $p < 0.01$; T2: $r = 0.22$; $p < 0.01$; T3: $r = 0.19$; $p < 0.01$; T4: $r = 0.23$; $p < 0.01$). Executive functions and VMI positively influence later mathematics performance
Brock et al. (2018) United States Longitudinal (3 years)	256	M 119 F 137	4.8–6.4 (5.41)	To explore the associations between executive function, VMI, and performance in reading and mathematics from kindergarten through second grade in economically disadvantaged children	**VMI** in kindergarten only predicts math performance in grade 1 (T2) (T1 to T2: $r = 0.17$; $p < 0.05$). Early interventions must be performed to develop VMI
Duran et al. (2018) United States Longitudinal (6.5 months)	162	M 81 F 81	(T1 5.5 T2 6.6)	To examine the associations between executive function, VMI, and mathematics performance in kindergarten and later in early first grade in students with low socioeconomic status	**VMI** is related to math performance (VMI – WJ III: $r = 0.50$; $p < 0.05$; VMI – TEMA: $r = 0.53$; $p < 0.05$; VMI – KeyMath3: $r = 0.53$; $p < 0.05$) and appears to have an additional and unique association in improving their performance

(Continued)

TABLE 2 (Continued)

Author country type of study	*N*	Sex	Age in years (mean)	Aim of the study	Study results and conclusions
Fischer et al. (2018) Germany Transverse	177	M 87 F 90	2.7–6.4 (4.6)	Investigate the relationship between FMC and procedural counting skills as well as conceptual counting knowledge	**FMC** is strongly related to procedural counting skills (FMC – Procedural counting: $r = 0.41$; $p < 0.01$) and (FMC conceptual – Conceptual counting: $r = 0.36$; $p < 0.01$), being a necessary prerequisite for sensorimotor experience of numbers through counting by fingers
Kim et al. (2018) United States Longitudinal (2 years)	134	D	4.9–6.8 (5.6)	Explore the longitudinal associations between VMI, attention, FMC, and math skills	Over time**VMI** predicted changes in math skills (VMI – KeyMath3: T1-T2: $\beta = 0.13$; < 0.001; T2-T3: $\beta = 0.14$; $p < 0.001$) and**FMC** was indirectly related as math performance through VMI (FMC – VMI: T1-T2: $\beta = 0.18$; < 0.01; T2-T3: $\beta = 0.14$; $p < 0.05$). Reciprocal associations exist between VMI, FMC, attention, and mathematics from early childhood through the early years of schooling
Manfra et al. (2017) United States Longitudinal (4 years)	1.442	M 688 F 754	4 years up to 3rd grade.	To explore the association between preschool academic skills and 3rd grade in children from low-income families	**VMI** and**FMC** in preschool math skills in 3rd grade (VMI: $\beta = 0.008$; < 0.01; FMC: $\beta = 0.012$; < 0.001)
Osorio-Valencia et al. (2017) Mexico Longitudinal (2 years)	148	D	3–5	To assess motor development in 3-year-old children and its relationship to their cognitive abilities at age 5	Only children's**FMC** and**VMI** at age 3 significantly influenced math performance at age 5 (FMC – Mat: $\beta = 0.74$, $p = 0.005$; VMI – Mat: $\beta = 2.11$, $p = 0.001$). Early motor assessment and stimulation and help create strategies that facilitate the acquisition of academic knowledge
Suggate et al. (2017) Germany Transverse	81	M 40 F 41	3.3–6.3 (4.9)	Explore whether FMC would correlate with numerical ability	**FMC** is closely related to finger-based numerical skills ($\beta = 0.23$, $p = 0.05$), allowing early development of numerical skills through counting by fingers
Becker et al. (2014) Northeast Pacific Transverse	127	D	4.4–6.6 (5.6)	Explore the contributions of behavioral self-regulation, two measures of executive function, and VMI on academic performance	**VMI** is significantly associated with math performance in the early years ($r = 0.59$; $p < 0.05$; $\beta = 0.13$; $p = 0.045$), and may be an indicator to inform teaching strategies in children with math difficulties
Verdine et al. (2014) United States Longitudinal (1 year)	44	M 22 F 22	3.2–4 (3.6) and later 4.3–5.2 (4.76).	Determine the contribution of spatial skills and executive function to early mathematics performance	There is a significant association between**VMI** and math skills in both evaluation moments (VMI – WIAT: $r = 0.673$; $p < 0.001$). VMI is a spatial predictor of math skills
Dinehart and Manfra (2013) United States Longitudinal (3 years)	3.224	M 1515 F 1709	(5.3 and 2 years later)	Examines whether the FMS of economically disadvantaged children predicts later academic performance	Children who performed better on the FMS (FMC and VMI) at the end of preschool were those who performed better in math in 2nd grade (FMC-LAP-D: $\beta = 1.75$; $p < 0.001$; VMI-LAP-D: $\beta = 1.20$; $p < 0.001$). FMS in preschool predicts math performance in 2nd grade

D, Does not discriminate; F, female; FMC, fine motor coordination; M, male; Mat, mathematics; *N*, number; *p*, significance level; *r* and R^2, correlation; T, time; TEMA-3, Test of early mathematics ability, 3rd edition; VMI, visuomotor integration; VSI, visuospatial integration; LAP-D, Learning Accomplishment Profile Diagnostic, 3rd Editions; T, assessment moment; WIAT – III, Wechsler Individual Achievement Test, 3rd edition; WJ-III, Woodcock-Johnson Achievement Test.

the maximum was up to the 5th grade (children between 10 and 11 years old; Greenburg et al., 2020).

The study conducted by Greenburg et al. (2020) was included in this review as the authors distinguished in their research two specific aspects of FMS (FMC and the integration of motor information with visual (VMI) and spatial (VSI) information), addressing in this study these specific motor skills only as VSI and not VMI skills (Table 2).

3.4. Associations between motor skills and mathematical performance

Regarding the study of the associations between motor skills and mathematics, considering the main conclusions from the 18 studies, only in the study carried out by De Waal (2019) whose objective was to determine if there were correlations between motor skills and the academic performance in preschoolers aged 5–6 years old, there was a moderate and significant correlation between a specific component of GMS, namely balance skills (dynamic and static) and mathematical performance ($0.46 > r > 0.23$; $p < 0.05$). On the other hand, FMS have been reported to be associated with mathematical performance in 17 studies (Table 2).

When analyzing the distribution of studies that associated mathematical performance with FMS, namely FMC and VMI, it was found that eight studies reported VMI (Becker et al., 2014; Verdine et al., 2014; Brock et al., 2018; Duran et al., 2018; Cameron et al., 2019; Nesbitt et al., 2019; Escolano-Pérez et al., 2020; Khng and Ng, 2021), four studies FMC (Suggate et al., 2017; Fischer et al., 2018, 2020; Clark et al., 2021) and five studies reported both FMS (FMC + VMI; Dinehart and Manfra, 2013; Manfra et al., 2017; Osorio-Valencia et al., 2017; Kim et al., 2018; Greenburg et al., 2020; Figure 4).

Among the VMI, FMS was the one that stood out the most among the 18 studies, having been reported in 13 (72%), and FMC was associated with mathematical performance only in nine (50%). Thus, among FMS, VMI (more than FMC) was more frequently associated with mathematical performance, and is still reported as an important factor for the diagnosis of learning disabilities in mathematics (Khng and Ng, 2021). However, both VMI and FMC were mentioned as strong predictors of mathematical performance in the present (VMI: Dinehart and Manfra, 2013; Becker et al., 2014; Duran et al., 2018; Khng and Ng, 2021; FMC: Dinehart and Manfra, 2013; Suggate et al., 2017; Fischer et al., 2020) and in the future (VMI: Verdine et al., 2014; Manfra et al., 2017; Osorio-Valencia et al., 2017; Brock et al., 2018; Cameron et al., 2019; Escolano-Pérez et al., 2020; Greenburg et al., 2020; CMF: Manfra et al., 2017; Osorio-Valencia et al., 2017; Greenburg et al., 2020).

In the frequency analysis of the association between MS and math skills (Figure 5 and Tables 3, 4), regarding GMS, namely balance, it was associated with the following math skills: counting, measurement (length), shapes and spatial relations (De Waal, 2019). Regarding FMS, both FMC and VMI were associated with all math skills (Figure 5; Tables 3, 4). However, counting was the math skill that was most frequently reported to be associated with FMS. It was associated with FMC in all nine studies (100%; Dinehart and Manfra, 2013; Manfra et al., 2017; Osorio-Valencia et al., 2017; Suggate et al., 2017; Fischer et al., 2018; Kim et al., 2018; Fischer et al., 2020; Greenburg et al., 2020; Clark et al., 2021) and with VMI (Dinehart and Manfra, 2013; Verdine et al., 2014; Manfra et al., 2017; Osorio-Valencia et al., 2017; Duran et al., 2018; Kim et al., 2018; Escolano-Pérez et al., 2020; Greenburg et al., 2020; Khng and Ng, 2021) in nine studies (53%). One can highlight the fact that measurement skills (length), shapes (Dinehart and Manfra, 2013; Manfra et al., 2017; Kim et al., 2018; Greenburg et al., 2020), cardinality (Osorio-Valencia et al., 2017; Fischer et al., 2018; Kim et al., 2018; Fischer et al., 2020), and comparing (Osorio-Valencia et al., 2017; Fischer et al., 2018, 2020; Clark et al., 2021) were reported in four studies. Only in one study number identification (Kim et al., 2018), addition, and subtraction (Suggate et al., 2017) were reported to be associated with FMC. Regarding VMI, except the math skill spatial relations, which was only reported in a single study (Kim et al., 2018), all other skills were reported in four or more studies. Thus, in six studies the number identification skill was reported (Verdine et al., 2014; Duran et al., 2018; Kim et al., 2018; Nesbitt et al., 2019; Escolano-Pérez et al., 2020; Khng and Ng, 2021), addition and subtraction (Becker et al., 2014; Brock et al., 2018; Duran et al., 2018; Cameron et al., 2019; Nesbitt et al., 2019; Khng and Ng, 2021), and measurement (length; Dinehart and Manfra, 2013; Manfra et al., 2017; Duran et al., 2018; Kim et al., 2018; Nesbitt et al., 2019; Greenburg et al., 2020). In five studies, the cardinality (Verdine et al., 2014; Osorio-Valencia et al., 2017; Duran et al., 2018; Kim et al., 2018; Escolano-Pérez et al., 2020) and shapes skills (Dinehart and Manfra, 2013; Manfra et al., 2017; Duran et al., 2018; Kim et al., 2018; Greenburg et al., 2020) were reported. The comparing skill was reported in four studies (Verdine et al., 2014; Osorio-Valencia et al., 2017; Nesbitt et al., 2019; Khng and Ng, 2021).

When analyzing data from studies exclusively involving children who attended preschool, it was found that all math skills were associated with both FMC and VMI: counting – in six studies – (Osorio-Valencia et al., 2017; Suggate et al., 2017; Fischer et al., 2018; Kim et al., 2018; Fischer et al., 2020; Clark et al., 2021) and cardinality (Osorio-Valencia et al., 2017; Fischer et al., 2018; Kim et al., 2018; Fischer et al., 2020) and comparing – (Osorio-Valencia et al., 2017; Fischer et al., 2018, 2020; Clark et al., 2021) in four studies – were the most frequently associated with FMC. Regarding VMI, the math skills most frequently associated with it were counting (Verdine et al., 2014; Osorio-Valencia et al., 2017; Kim et al., 2018; Escolano-Pérez et al., 2020; Khng and Ng, 2021) and number identification (Verdine et al., 2014; Kim et al., 2018; Nesbitt et al., 2019; Escolano-Pérez et al., 2020; Khng and Ng, 2021), both in five studies, and cardinality (Verdine

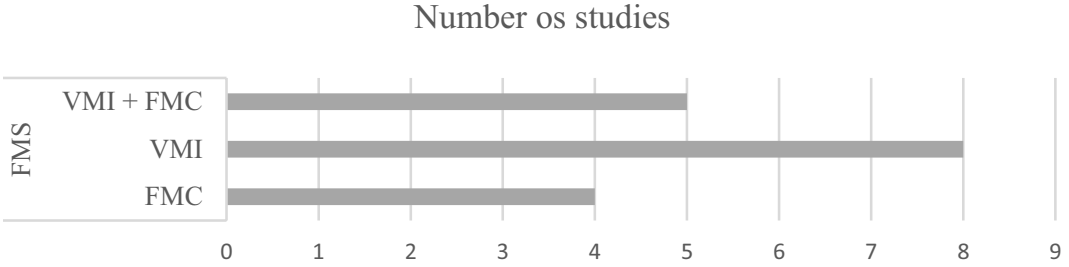

FIGURE 4
Distribution of studies associating FMS, FMC and VMI to math skills. FMC, fine motor coordination; FMS, fine motor skills; VMI+FMC, visuomotor integration plus fine motor coordination.

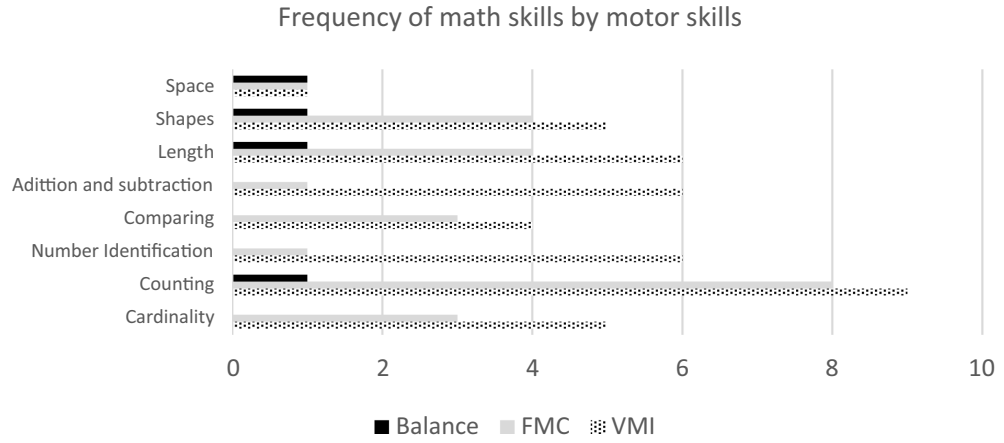

FIGURE 5
Distribution of studies associating FMS (FMC and VMI) and balance with math skills. FMC, fine motor coordination; VMI, visuomotor integration.

et al., 2014; Osorio-Valencia et al., 2017; Kim et al., 2018; Escolano-Pérez et al., 2020), comparing (Verdine et al., 2014; Osorio-Valencia et al., 2017; Nesbitt et al., 2019; Khng and Ng, 2021), and addition and subtraction (Becker et al., 2014; Cameron et al., 2019; Nesbitt et al., 2019; Khng and Ng, 2021) in four studies.

These results suggest that counting, cardinality, and comparing were the math skills most associated with FMC; and counting, number identification, cardinality, comparing, and addition and subtraction with VMI. However, the math skill of counting was the most commonly associated with FMS (FMC and VMI), as of the 17 studies that analyzed this math skill, it was associated with FMS in 13 (76%; Tables 3, 4).

3.5. Instruments used in the studies to assess motor and math skills

In the 18 studies included, 10 instruments were used to assess motor skills (Table 4).

In the only study that associated GMS with mathematical performance (De Waal, 2019), the Kinder kinetics Screening test was used (Pienaar et al., 2016).

To assess FMS, nine instruments were used. To exclusively assess FMC, three instruments were identified: Grooved Pegboard Test (GPT, Strauss et al., 2006; Clark et al., 2021); Movement Assessment Battery for Children, 2nd edition (MABC-2, Henderson et al., 2007; Fischer et al., 2020); Battery designed to provide an estimate of children's fine motor skills in preschool (BEFMS, Martzog, 2015). To exclusively assess VMI, four instruments were identified: The Brigance Inventory of Early Development III — Standardized (IED III, French, 2013; Khng and Ng, 2021); Test of Visual-Motor Integration, 6th edition (VMI, Beery and Beery, 2010; Becker et al., 2014; Verdine et al., 2014; Brock et al., 2018; Cameron et al., 2019; Escolano-Pérez et al., 2020); Copy Design Task (CDT, Osborn et al., 1984; Nesbitt et al., 2019); NEuroPSYchological assessment battery, 2nd edition (NEPSY, Korkman et al., 1998; Duran et al., 2018). To simultaneously assess FMC and VMI, three instruments were identified: Learning Accomplishment Profile-Diagnostic, 3rd edition (LAP-D, Nehring et al., 1992; Dinehart and Manfra, 2013; Manfra et al., 2017; Greenburg et al., 2020); (NEPSY, Korkman et al., 1998; Kim et al., 2018); Peabody developmental motor scale, 2nd edition (PDMS-2, Folio and Fewell, 2000; Osorio-Valencia et al., 2017; Table 4).

For the assessment of mathematical performance, 16 instruments were identified among the 18 studies (Table 4).

Only in one study it was identified: Mathematics Sharing Stories, Cwikla, 2014 (Clark et al., 2021); Dot Counting Task, Clark et al., 2021 (Clark et al., 2021); Test of basic instrumental aspects: reading, writing and numerical concepts (PAIB-1, Galve-Manzano et al., 2009; Escolano-Pérez et al., 2020); Finger-based number representations (Wasner et al., 2015; Fischer et al., 2020); Number tasks (Nosworthy, 2013; Fischer et al., 2020); Foundations for learning: Assessment Framework Grade R (De Waal, 2019); McCarthy Scales of Children's Abilities (MSCA, McCarthy, 2004; Osorio-Valencia et al., 2017); Numerical skills (Dowker, 2008; Suggate et al., 2017); Nonfinger-based numerical skills and Finger-based numerical skills (Crollen et al., 2011; Suggate et al., 2017); Wechsler Individual Achievement Test, 3rd edition (WIAT-III, Wechsler, 2007; Verdine et al., 2014).

It was identified in two studies: Test of Early Mathematics Ability – 3rd edition (TEMA-3, Ginsburg and Baroody, 2003; Duran et al., 2018; Khng and Ng, 2021); Test for diagnosing basic math skills (TEDI-MATH, Kaufmann et al., 2009; Fischer et al., 2018, 2020); KeyMath-3 Diagnostic assessment (KeyMath3, Connolly, 2007; Duran et al., 2018; Kim et al., 2018).

The Learning Accomplishment Profile-Diagnostic, 3rd edition (LAP-D, Nehring et al., 1992; Dinehart and Manfra, 2013; Manfra et al., 2017; Greenburg et al., 2020) was identified in three studies.

The Woodcock-Johnson Tests of Achievement (WJ-III, Woodcock et al., 2001; Becker et al., 2014; Brock et al., 2018; Duran et al., 2018; Cameron et al., 2019; Nesbitt et al., 2019) was identified in five studies.

Thus, of the seven instruments used to assess VMI, the VMI test (Beery and Beery, 2010) was the most used, as it was reported in five studies. To assess FMC, the most commonly used instrument was the LAP-D (Nehring et al., 1992) in three studies (Table 4).

The main characteristics of the instruments used in the assessment of VMI require tasks of copying geometric figures, letters, numbers or objects, using a sheet of paper and pencil. To assess FMC, the main characteristics of the instruments used allowed the assessment of dexterity and manual speed through tasks that demand the handling and manipulation of objects such as threading beads, placing coins, building blocks, turning cylinders, folding paper or cutting it with scissors.

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TABLE 3 Frequencies of associations between motor skills and mathematics by teaching frequency.

Author and year	Teaching frequency	Motor Skills			Math Skills							
		FMC	VMI	Bl	A	B	C	D	E	F	G	H
Clark et al. (2021)	Preschool education	X				+		+				
Khng and Ng (2021)	Preschool education		X			+	+	+	+			
Escolano-Pérez et al. (2020)	Preschool education		X		+	+	+					
Fischer et al. (2020)	Preschool education	X			+	+		+				
Greenburg et al. (2020)	From Preschool education to 5th grade	X	X			+				+	+	
Cameron et al. (2019)	Preschool education		X						+			
De Waal (2019)	Preschool education			X		+				+	+	+
Nesbitt et al. (2019)	Preschool education		X				+	+	+	+		
Brock et al. (2018)	Preschool education to 2nd grade		X						+			
Duran et al. (2018)	Preschool education to 1st grade		X		+	+	+		+	+	+	
Fischer et al. (2018)	Preschool education	X			+	+		+				
Kim et al. (2018)	Preschool education	X	X		+	+	+			+	+	+
Manfra et al. (2017)	Preschool education to 3rd grade	X	X			+				+	+	
Osorio-Valencia et al. (2017)	Preschool education	X	X		+	+		+				
Suggate et al. (2017)	Preschool education	X				+			+			
Becker et al. (2014)	Preschool education		X						+			
Verdine et al. (2014)	Preschool education		X		+	+	+	+				
Dinehart and Manfra (2013)	Preschool education to 3rd grade	X	X			+				+	+	
TOTAL		9	13	1	7	14	6	7	7	7	6	2

Math Skills: (A – cardinality; B – Counting; C – Numbers Identification; D – Comparing; E – Addition and subtraction; F – Length; G – Shapes; H – Space); FMC, Fine Motor Coordination; MS, Motor Skills; Bl, Balance; VMI, Visuomotor Integration.

4. Discussion

The objective of this systematic review was to analyze preschool education children with typical development in the association between motor skills and mathematical performance, identify the math skills involved in this association, as well as the instruments used for this purpose to evaluate both motor skills and mathematics.

Based on the results, in relation to the first objective, there was sufficient evidence to support the associations between FMS, namely FMC and VMI, and mathematical academic performance of the children who attended preschool education with typical development. It is noteworthy that only one study has considered associations between a component of GMS, namely balance, and mathematical academic performance (De Waal, 2019).

Similar results to this study were obtained in a systematic review that sought to report the relationships between motor proficiency and academic performance in mathematics and reading in school-age children and adolescents (Macdonald et al., 2018). The authors concluded that FMS were significantly associated with the performance of math skills, particularly in the early school years, and there was no consistency or sufficient evidence to support associations between the specific components of GMS and academic math performance. Likewise, in a systematic review carried out by Van der Fels et al. (2015), in children aged between 4 and 16 years with typical development, most observational studies (86%) reported significant positive associations between FMS and academic performance, especially in children who attended the preschool education up to the 2nd grade.

Studies have shown that GMS are critical for the development of social skills as well as for physical well-being (Cameron et al., 2016), as they influence children's level of physical activity and health (Logan et al., 2015; Hamilton and Liu, 2018). On the other hand, FMS have been more strongly associated with academic performance (Cameron et al., 2016) and found to influence children's ability to perform visual motor integration activities, which is important for classroom activities (Strooband et al., 2020). It has been suggested that, at school age, GMS may be important for social affirmation (Ommundsen et al., 2010) and perceived athletic competence (Piek et al., 2006), and FMS for school readiness (Grissmer et al., 2010) and perceived academic competence (Piek et al., 2006).

Despite different purposes, research has shown that during child development, GMS and FMS seem to have some correlation (Roebers and Kauer, 2009; Cameron et al., 2012; Dayem et al., 2015; Oberer et al.,

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TABLE 4 Instruments used in the association between motor skills and math skills.

Author (year)	Motor skills			Math skills	
	Instr	MS	Evaluation	Instruments	Skills
Clark et al. (2021)	GPT	FMC	The GPT task was used to fit pins into hole. It is a widely used measure that requires dexterity and manual speed	Shared story task Point counting task	Counting and comparing
Khng and Ng (2021)	IED III	VMI	Use of the Fine Motor Subscale. The tests administered were: Visual motor skills; Drawing of a person; Writing the sequence of numbers; Sequential drawing of capital letters	TEMA-3 (Formal and informal knowledge)	Counting, comparing, numbers identification, addition and subtraction
Escolano-Pérez et al. (2020)	VMI	VMI	The VMI was assessed using the tests: Copy Shapes, Letters Words and Numbers	PAIB-1 (Basic Aspects of Mathematics Quiz)	Cardinality, counting and identification of numbers
Fischer et al. (2020)	MABC-2	FMC	The FMC was evaluated using the Manual Dexterity Scale: placing coins in a box with a slot; string beads on a cord	Finger-Based Number Representations (finger counting; finger montring) Numerical Tasks (Non-symbolic dot comparison; Symbolic number comparison; Verbal counting sequence)	Counting and cardinality (Finger-Based Number Representations); Comparing and counting (Numerical tasks)
Greenburg et al. (2020)	LAP-D	VSI FMC	The VSI was assessed by the Writing Subscale, which includes tasks with pencil and paper, such as copying numbers, letters, and shapes, and drawing objects. The FMC was evaluated by the object manipulation subscale with paper folding, building blocks, cutting with scissors	LAP-D (Counting and matching subscales)	Counting, measurement (length) and shapes
Cameron et al. (2019)	VMI	VMI	The VMI was evaluated through the test VMI that assesses the visual and motor skills in an integrated way. The test requires the child to copy increasingly complex geometric figures as the test progresses	WJ-III (Application of problems subscale)	Addition and subtraction
De Waal (2019)	Kinder kinetics Screening	Balance	Assesses basic movement skills, locomotor, postural (static and dynamic balance) and manipulative in children aged 3–6 years	Foundations for learning: Grade R Assessment Framework R	Counting, measurement (length), shapes and space
Nesbitt et al. (2019)	CDT	VMI	The VMI was evaluated by the task of copying geometric drawings	WJ-III (Application of problems sub-scale and quantitative concepts sub-scale)	Addition and subtraction (application of problems sub-scale); numbers identification; Comparing and measurement (length) (quantitative concepts sub-scale)
Brock et al. (2018)	VMI	VMI	Idem Cameron et al. (2019)	WJ-III (Application of problems subscale)	Addition and subtraction
Duran et al. (2018)	NEPSY	VMI	The VMI was evaluated by the NEPSY Design Copying Subtest. In this test, the children used paper and pencils to copy two-dimensional geometric drawings of increasing complexity	WJ-III (Application problems subscale) KeyMath-3 (Numeracy, geometry and measurement subscales) TEMA-3 (Formal and informal concepts and skills)	Addition and subtraction (WJ-III); Number identification, shapes and measurement (length) (KeyMath3); Counting, cardinality, number identification, adding and subtracting and measurement (length) (TEMA-3)

(Continued)

TABLE 4 (Continued)

Author (year)	Motor skills			Math skills	
	Instr	MS	Evaluation	Instruments	Skills
Fischer et al. (2018)	BEFMF	FMC	3 tasks: Pegboard task (inserting pins into a board), Bead threading (threading beads) and Block turning (turning cylinders, measured speed and fine motor coordination). These are measures used that require manual dexterity	TEDI-MATH (Counting subtest)	Counting, cardinality and comparing
Kim et al. (2018)	NEPSY	VMI	The VMI was evaluated by the Design Copying subtest. In this test, the children used paper and pencils to copy two-dimensional geometric drawings of increasing complexity	KeyMath-3 (Numeracy, geometry and measurement subscales)	Cardinality, counting, number identification, shapes, space and measurement (length)
		FMC	The FMC was evaluated by the *precision* subtest and assesses the speed and accuracy of hand-eye coordination. The total score considers the speed and accuracy scores		
Manfra et al. (2017)	LAP-D	FMC	The FMC was assessed by the Fine Motor Manipulation Subscale (manipulating small objects)	LAP-D (Count and correspondence subscales)	Counting, measurement (length) and shapes
		VMI	The VMI was assessed by the Writing Subscale which includes tasks with pencil and paper, such as copying numbers, letters, and shapes and drawing objects		
Osorio-Valencia et al. (2017)	PDMS-2	VMI	VMI was evaluated through the prehension and visuomotor integration subtests	MSCA (Quantitative scale)	Cardinality, counting and comparing
Suggate et al. (2017)	BEFMS	FMC	3 tasks: Pegboard task (inserting pins into a board), Bead threading (threading beads) and Block turning (turning cylinders, measured speed and fine motor coordination). These are measures used that require manual dexterity	Numerical skills	Counting and adding and subtracting
				Nonfinger-based numerical skills	
				Finger-based numerical skills	
Becker et al. (2014)	VMI	VMI	The VMI was assessed using the VMI which evaluates visual and motor skills in an integrated manner. The test requires the child to copy increasingly complex geometric figures as the test progresses	WJ – III (Application of problems subscale)	Addition and subtraction
Verdine et al. (2014)	VMI	VMI	The VMI was assessed using the VMI which evaluates visual and motor skills in an integrated manner. The test requires the child to copy increasingly complex geometric figures as the test progresses	WIAT-III (Problem-solving subtest)	Counting, cardinality, number identification and comparing
Dinehart and Manfra (2013)	LAP-D	FMC	The FMC was assessed by the Fine Motor Manipulation Subscale (manipulating small objects)	LAP-D (Counting and matching subscales)	Counting, measurement (length) and shapes
		VMI	The VMI was assessed by the Writing Subscale which includes tasks with pencil and paper, such as copying numbers, letters, and shapes and drawing objects		

BEFMS, Battery designed to provide an estimate of children's fine motor skills in preschool; FMC, Fine Motor Coordination; MS, Motor Skills; IED III, The Brigance Inventory of Early Development III; Instr, Instruments; VMI, visuomotor integration; KeyMath3, KeyMath-3 Diagnostic assessment; LAP-D, Learning Accomplishment Profile-Diagnostic, 3rd edition; MABC-2, Movement Assessment Battery for Children, 2nd edition; PDMS, Peabody developmental motor scale, 2nd edition; MSCA, McCarthy Scales of Children's Abilities; NEPSY, NEuroPSYchological assessment battery; PAIB-1, Test of basic instrumental aspects: Reading, writing and numeric concepts; CDT, Copy Design Task; TEDI-MATH, Test for the diagnosis of basic skills in mathematics; TEMA-3, Test of Early Mathematics Ability – 3rd edition; GPT, Grooved Pegboard Test; VMI, Test of Visual-Motor Integration; WIAT-III, Wechsler Individual Achievement Test, 3rd edition; WJ-III, Woodcock-Johnson Tests of Achievement.

2017), as higher order neuromotor processes seem to be involved simultaneously in the learning of GMS and FMS (Roebers and Kauer, 2009; Oberer et al., 2017). However, studies that investigated the relationship between GMS and FMS, at different stages of school education, obtained controversial results when comparing measures of individual performance of GMS and FMS (Cameron et al., 2012; Amaro et al., 2014; Dayem et al., 2015; Tortella et al., 2016; Oberer et al., 2017). Cameron et al. (2012) and Oberer et al. (2017) showed a moderate correlation between GMS and FMS. Specifically, Oberer et al. (2017) reported a positive correlation in children aged between 5.6 and 7.25 years, assessing gross and fine motor skills through speed and accuracy tasks. Likewise, the investigation by Cameron et al. (2012) also reported a positive correlation in younger children (3–4 years) between GMS, namely balance and jumping and jumping tasks, and FMS, namely building tasks using blocks and drawing tasks. In addition, Dayem et al. (2015), showed an even greater correlation between GMS (assessed by locomotor tasks, object manipulation, and balance tasks) and FMS (assessed by writing tasks) in children aged 4–6 years. On the other hand, other authors disagree on the positive correlation between GMS and FMS (Souza et al., 2010; Amaro et al., 2014; Tortella et al., 2016). The study carried out by Tortella et al. (2016) reported that there was no correlation between GMS and FMS in preschool education children aged between 5 and 6 years, evaluating GMS through precision, balance, throwing, and walking tasks, while FMS were evaluated using speed and precision tasks, such as block constructions and placing coins. Additionally, Souza et al. (2010), when investigating global motor performance using the Bayley Scales of Infant and Toddler Development (Third Edition), found a weak correlation between GMS and FMS. Furthermore, Amaro et al. (2014) did not reported any correlation between GMS and FMS in children aged between 5 and 10 years when comparing the scores obtained in the "Körperkoordinationtest für kinder" and the Minnesota manual dexterity test. These contrasting results can be attributed to the fact that motor skills do not follow linear development trajectories (Souza et al., 2010; Flatters et al., 2014a). Therefore, it is not surprising that investigating children of different ages can produce different results. In addition, these studies assessed motor skills over short periods using heterogeneous tasks (Sorgente et al., 2021).

However, it is important to note that in the same action it is complex to unequivocally differentiate the involvement of each of the motor skills (GMS and FMS), as they coexist and are fundamental for the efficient performance of the task, as both are related and influence each other (Payne and Isaacs, 2012; Flatters et al., 2014b). In this sense, GMS are influenced and influence FMS, the first being also a good predictor of children's school learning (Sortor and Kulp, 2003; Beery and Beery, 2006; Henderson et al., 2007; Spanaki et al., 2008; Kambas et al., 2010; Kadkol et al., 2014; Byers et al., 2016; Africa and Deventer, 2017; Bellocchi et al., 2017).

However, there are very few studies in the literature that investigated the association between GMS and academic performance (De Waal, 2019; Sorgente et al., 2021), so it is a topic that can be the subject of further research.

Although in this review only one study associates GMS, namely balance, with mathematical performance (De Waal, 2019), it should also be analyzed. In a study carried out by Vuijk et al. (2011), the authors also found significant correlations between balance and mathematics, however this study was developed in children with learning difficulties at school age. Balance, especially when vision is not used, depends a lot on the effective functioning of the vestibular system involved in the execution of controlled movements (Cheatum and Hammond, 2000). In this sense, problems in the vestibular system not only lead to delays in motor proficiency, but can also negatively affect the performance of activities in the classroom (Cheatum and Hammond, 2000). However, in a recent systematic review, the results concluded that balance did not significantly correlate with mathematical academic performance, as in other GMS considered (Macdonald et al., 2018). Regarding FMS, of the 17 studies that associated these skills with mathematical performance, VMI was the one that stood out the most, being reported in 13 studies (76%), followed by FMC in nine (53%). However, by itself, this result does not mean that the VMI of FMS will be the most predictive of mathematical performance, as studies that included the two FMS concluded that FMC and VMI were both predictors of mathematical performance (Dinehart and Manfra, 2013; Manfra et al., 2017; Kim et al., 2018; Greenburg et al., 2020), except the study carried out by Fischer et al. (2020), in which FMC was the only one associated with mathematical performance and the studies conducted by Escolano-Pérez et al. (2020) and Osorio-Valencia et al. (2017), in which on the contrary, VMI was the only one associated with mathematical performance. Studies in which only FMC (Suggate et al., 2017; Fischer et al., 2018; Clark et al., 2021) or VMI (Becker et al., 2014; Verdine et al., 2014; Brock et al., 2018; Duran et al., 2018; Cameron et al., 2019; Nesbitt et al., 2019; Khng and Ng, 2021) were analyzed concluded that these motor skills were associated with mathematical performance. Thus, each FMS was used according to the aim of each study. In this sense, although VMI appears as the most frequently associated with mathematical performance, it does not mean *a priori* that it will have a greater degree of importance than FMC. These results suggest that both FMS (FMC and VMI) are important predictors of mathematical performance depending only on the objectives of the studies and instruments used for this purpose.

VMI involves the integration of visual and motor skills (Sortor and Kulp, 2003; Beery and Beery, 2006) coordinated through the fingers and hands, that is, FMC (Gabbard et al., 2001; Beery and Beery, 2006; Feder and Majnemer, 2007; Bezrukikh and Terebova, 2009; Kambas et al., 2010; Kadkol et al., 2014; Byers et al., 2016). In this sense, VMI implies the mental representation of an image that is replicated by controlling the meticulous movement of the fingers (Carlson et al., 2013). Thus, FMC plays a very important role in school success (Sortor and Kulp, 2003; Roebers et al., 2014; Kim et al., 2015; Fischer et al., 2020) because children with better FMC will be better at handling objects such as pencils or notebooks, which allows them to direct additional attention resources toward learning, rather than focusing them on movements associated with FMC (Kim et al., 2018). FMC can also serve as a fundamental competency by which more complex processes can be built (Sortor and Kulp, 2003), namely for the development of VMI skills (Kim et al., 2018). There is also some evidence that FMC is linked to mathematics through its contribution to the development of VMI (Kim et al., 2018). Thus, a child with good FMC, when performing an academic task, may impose a lower cognitive load compared to a child who still has difficulties in FMC (Luo et al., 2007; Cameron et al., 2015). Cameron et al. (2012) conducted an observational study in classrooms at preschool education and found that 46% of the school day was dedicated to activities involving FMS (FMC and VMI). These activities included tasks such as writing, drawing, using scissors to cut paper, bean counting tasks, and playing with toys like building blocks and Legos. In this sense, FMC and VMI are considered essential for early (Lillard, 2005) and interdependent learning (Kim et al., 2018), proving to be a powerful predictor for school readiness (Bala et al., 2010; Grissmer et al.,

2010), adaptation and transition from the preschool education to the 1st grade (Bart et al., 2007) and end of 6th grade (Pagani et al., 2010) and also a great predictor of subsequent academic performance, especially in reading and mathematics (Cameron et al., 2012; Dinehart and Manfra, 2013). On the other hand, low levels of performance in FMS are associated with learning difficulties in the areas of reading, writing, and mathematics (Coetzee and Gerber, 2018).

Another objective of this study was to verify the frequencies with which math skills were associated with MS. Regarding GMS, only balance (static and dynamic) was associated with the math skills of counting, measurement (length), shapes, and space (De Waal, 2019). Despite these data, and as only the study of De Waal (2019) with a relatively small sample ($n = 30$) associated balance with math skills, it would be too premature to conclude in a sustained way the influence of this HMG on math skills. It is suggested that further studies consider the association between balance and math skills in order to support such conclusions.

Regarding FMS, all math skills proposed for Preschool Education (National Research Council, 2009) were associated with both FMC and VMI. Regardless of the type and characteristics of the studies, counting was the math skill most often associated with FMS, FMC, and VMI.

Counting can be seen as an infinitely long and ordered list of numbers that allows you to quantify what you want. In essence, counting is a way of doing a 1 to 1 correspondence between objects. Generally, each successive counting number describes a quantity that is one more than the previous quantity. Similarly, counting backwards is subtracting one from the previous number (National Research Council, 2009). In this sense, children, in addition to developing the notion of cardinality (Hannula, 2005), are performing addition and subtraction actions that are fundamental for solving problems (Siegler and Shrager, 1984). Children who make frequent counting errors have difficulty calculating (Geary et al., 2007). Since children show a spontaneous tendency to count, educators should take advantage of this to stimulate their practice with the aim of developing not only counting skills but other associated math skills (Hannula, 2005).

Another objective of this review was to describe the instruments used in the studies to assess and associated motor skills with mathematics. Regarding motor skills, in the 18 studies, 10 instruments were used. The study that assessed and associated one of the GMS (balance) with mathematical skills (De Waal, 2019), the Kinder kinetics Screening test was the instrument used (Pienaar et al., 2016). This instrument assesses the basic skills of fundamental movements in children aged between 3 and 6 years. The skills assessed were the fundamental locomotor, balance (dynamic and static), and object manipulation skills (Pienaar et al., 2016).

Regarding FMS, nine instruments were used in the 17 studies analyzed, three to assess FMC exclusively, four to assess VMI and three to assess both FMC and VMI.

In the assessment of FMS, although the LAP-D (Nehring et al., 1992) was the most used (three studies), its characteristics are similar to the other instruments used only in a study each, namely the NEPSY (Korkman et al., 1998), and the MABC-2 (Henderson et al., 2007), the BEFMS (Martzog, 2015), and the PDMS-2 (Folio and Fewell, 2000). Thus, these instruments assess manual dexterity and speed through tasks such as fitting pins, turning cylinders, stringing beads, building with blocks, folding paper, cutting with scissors, and putting coins in a slot.

In the assessment of VMI, the most commonly used instrument was the VMI (five studies; Beery and Beery, 2010). Although this instrument was the most commonly used, its tasks are also similar to the other instruments used in the assessment of VMI. The main tasks assessed by these instruments consist of copying geometric figures, letters or numbers, and drawing objects using a sheet of paper and pencil.

The literature has shown that the tasks of copying figures or drawing are the most used tasks to assess VMI, and object handling tasks with pinch-like movements are the most used to assess FMC (Davis and Matthews, 2010; Carlson et al., 2013; Newman and Feinberg, 2015; MacDonald et al., 2016).

The literature shows the importance that the instruments used to assess the development of motor skills have in tracking possible difficulties associated with mathematical performance (Kim et al., 2015). Most of these studies used direct neuropsychological assessments (Kim et al., 2015), such as the NEuroPSYchological Assessment Battery – NEPSY (Korkman et al., 1998) and the Visuomotor Integration test (VMI; Beery and Beery, 2010). However, it is recognized that these instruments are usually time consuming and expensive and are only administered by experts for this purpose (Cameron et al., 2012; Williford et al., 2013). In this sense, the characteristics of the instruments most used for the diagnosis of difficulties associated with mathematical performance may be a limitation in relation to the reality of kindergartens. Thus, the main instruments cited in the literature for the assessment of motor skills associated with mathematical performance practically make it impossible for educators to carry out these assessments on their students (Kim et al., 2015).

Regarding the instruments to assess math skills, in the 18 studies analyzed, 16 different instruments were used. Most studies, 78% (14), used only one instrument, the remaining 22% (4) used more than one, depending on the proposed objective. However, the instrument most used to assess math skills was WJ-III (application problems subscale; Woodcock et al., 2001). The WJ-III battery is considered the most complete to explain intellectual functioning, existing in two versions, the first design to assess cognitive abilities (standard form) and the second to assess academic performance (Mather and Gregg, 2002).

It is noteworthy that in the three studies that used the same instrument, namely the LAP-D, to assess FMS (FMC and VMI) and math skills (Dinehart and Manfra, 2013; Manfra et al., 2017; Greenburg et al., 2020) the result was similar, as FMS were associated with the same math skills: counting, measurement (length), and shapes. The LAP-D is an instrument used to measure children's academic readiness during preschool education. It includes domains for cognitive development, mathematics, and language, and FMS, which includes tasks to assess FMC and VMI (Nehring et al., 1992).

Similarly, in the three studies that used the same instruments for the assessment of both FMS and math skills, the results were similar, i.e., the studies that used the VMI test (Beery and Beery, 2010) for the assessment of FMS and the WJ-III (Woodcock et al., 2001) for the assessment of math skills recorded a significant association between VMI and the same math skills: addition and subtraction (Becker et al., 2014; Brock et al., 2018; Duran et al., 2018; Cameron et al., 2019).

On the other hand, when different instruments were used in the assessment of motor and math skills, the results were different. This suggests that each instrument should measure exactly what it sets out to measure considering the objectives outlined by the researchers (Roberts and Priest, 2006; Mokkink et al., 2010).

The results of this review may have important implications for the implementation of new strategies for teaching mathematics in preschool, as evidence was sufficient to support the influences of FMS (FMC and VMI) on mathematical academic achievement.

It has also been suggested that math skills are improved primarily from an age-adjusted math teaching intervention, better preparing children for school tasks (Sarama and Clements, 2004). However, cognitive skills arise from experiences, motor skills, and sensory-motor skills (Barsalou, 2010; Fischer, 2012). Most often children learn number skills with the help of objects that are typically small (cubes, buttons, etc.; Sarama and Clements, 2016) which requires precise fine motor handling (Luo et al., 2007). This handling will only be effective if the child is aware of the quantities represented by the object (Sarama and Clements, 2016). If the child has a deficit in FMS, it will be more difficult for the child to assign quantitative meaning to objects because the child will focus more on the fine motor actions than on the quantity of the objects (Carr and Davis, 2001). This finding contributes to support that children with learning disabilities in mathematics exhibit the least proficient FMS (Pieters et al., 2012). Since FMS can be automated (Floyer-Lea and Matthews, 2004), interventions in FMS will be recommended to free up cognitive resources for other learning tasks.

In this sense, the preschool curriculum should include guidelines to promote the development of FMS and thus better prepare children for mathematical learning. But, in order to plan a program to promote the development of FMS, a prior assessment of the child is necessary. However, educators lack training to assess FMS, and thus limitations to design appropriate programs adjusted to the needs (Gehris et al., 2015; Cueto et al., 2017).

5. Conclusion

This systematic review contributes considerably to the literature, as it found only evidence that supports positive associations between FMS, namely FMC and VMI, and mathematical performance in children with typical development in preschool education, with counting being the mathematical skill most associated with FMS (FMC and VMI). The main characteristics of the instruments used showed that the tasks of copying of figures or drawing are the most used to assess VMI and the tasks of handling objects with pinch-like movements are the most used to evaluate FMC. However, it has been recognized that these instruments are usually time consuming and expensive and are generally only administered by experts for this purpose.

Given the importance of FMS in mathematical skills, there is an urgent need to empower educators with tools to enhance the development of FMS in the classroom context. In this sense, early identification of children with difficulties in fine motor skills will help educators to design better strategies for teaching mathematical skills. Since the initial assessment is fundamental to plan an intervention adjusted to the child, it will be necessary to identify instruments with characteristics that allow their application in the classroom context, i.e., that require little administration time, do not require much experience or training, the possibility of being applied to the group/class, few material resources, and the results can be easily interpreted, classified, and associated with mathematical performance.

5.1. Limitations

It is essential to recognize that there were also some limitations in this review. First, it is important to point out that there is an evident gap in the literature of studies that report the association between gross motor skills and mathematical performance in preschool children. Second, there is the considerable heterogeneity of instruments used across studies to assess motor and math skills, making it difficult to compare and clearly interpret the results across studies. Third, the fact that some included studies report covariates that may influence the results, such as demographic factors (for example, socioeconomic status) and cognitive factors (such as executive function and its components). Covariates reported by each eligible study were not discussed as they were beyond the scope of this review.

5.2. Recommendations and implications for future research

In order to allow a more accurate comparison of results between studies in the future, researchers should consider consistent use of valid, reliable, and homogeneous standardized instruments. In addition, studies should control demographic, cognitive and physical confounding factors. Finally, as students with neurodevelopmental disorders attend regular schools, future investigations should also examine the relationships between motor and math skills in this population to inform possible forms of intervention.

5.3. Recommendations and implications for policies and practices

As it is known that children with FMS difficulties may present negative mathematical performance and given the importance of math performance in future school results, early identification of these difficulties will help educators to design better strategies for teaching math skills. However, although the main instruments reported in the literature accurately assess FMS, these instruments tend to be expensive, time-consuming to administer, require individualized assessments, demand a lot of training and experience, and are usually administered by experts. Thus, the characteristics of most instruments for the evaluation of FMS reveal limitations in the view of our kindergartens' reality. In this way, their administration in the classroom context by educators can be very conditioned taking into account the characteristics of most classes, which are very numerous and with very extensive curricula.

Due to its importance for academic success, it is considered that educators should carry out an assessment of the development of FMS to their students, in order to detect possible problems associated with mathematical performance. Eventually, if the child shows development problems in FMS, he/she should be referred for a specialized evaluation by a technician with qualifications for this purpose. For this reason, there is an urgent need for a new instrument to evaluate FMS in preschool education children with the ability to adjust to the reality of our kindergartens, that is, one that requires less administration time, does not require much experience or specialized training, has the possibility of being administered to the group/class in a classroom school context, requires few material resources and produces results that can be easily interpreted, classified and associated with mathematical performance. In this sense, this instrument can be a starting point for the early detection of FMS deficits and, consequently, the referral of the child for a new reassessment by a qualified professional. Furthermore, if the child has problems at this level, he or she may benefit from a timely intervention by a specialist and, consequently, prevent/reduce his/her difficulties in mathematical performance.

However, despite FMS being significantly associated with math performance, these skills also require the involvement of GMS. In this sense, it would be important to know which GMS can have the most influence on FMS so that a possible motor intervention program is more efficient and more likely to be successful.

For future research, we suggest the identification of instruments to assess fine motor skills in preschool children, with characteristics that allow their administration by the educator in the classroom context.

Author contributions

PFl: conceptualization and writing draft preparation. PFl, EC, MM-C, and PFo: methodology and research. PFl, MM-C, and PFo: formal analysis. EC, MM-C, and PFo: writing revision and editing and supervision. All authors have read and agreed to the version of the manuscript.

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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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A bibliometric review of coach leadership studies

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This study examined published articles concerning sports leadership within the sport psychology domain over the last 30 years using bibliometric analysis that centered on the written content of the publications as unit of analysis in order to explore the intellectual base, particularly the structural relationships among relevant research components about coach leadership. Leximancer version 5.0 (Leximancer Pty Ltd.) was used to extract data from 100 sports leadership-related articles from four sport psychology journals. Overall, the most relevant concepts generated were coaches (100%) and athletes (59%), followed by study, sport, support, and motivation, and behaviors. Also, relevant concepts produced for each journal were quite similar which included coaches, athletes, behaviors, study, support and team. Further, publications related to coach leadership have shown a steady growth rate since 1990 with 76% of all published articles were conducted *via* quantitative research method. Finally, United States, Canada, the United Kingdom, and Belgium were the top countries involved in the area of coach leadership. Coach leadership studies generally focus on behaviors and perceptions related to the coach and relationships between leadership and psychological outcomes. Each journal has a similar but distinct rationale when publishing papers about coach leadership. Bibliometric analysis can be applied as an alternative methodology to summarize large volumes of relevant data in order to map the current knowledge as well as identify potential future research directions.

KEYWORDS

sport psychology, Leximancer, coach, sport leadership, review, text analytics, athlete performance measure

1. Introduction

Sports coaches are recognized as important sports leaders. Their leadership roles are also regarded as being highly multifaceted (Weinberg and Gould, 2015). These roles can be providing training and instruction, teaching sport-specific tactics and strategies, motivating players during training and competition, fostering open communication among players, and creating a conducive sports environment to enhance sports performance (Weinberg and Gould, 2015; Kim and Cruz, 2016; Cruz and Kim, 2017). Effective delivery of these leadership roles from the coach can result in positive changes in behaviors (Allan and Côté, 2016; O'Neil and Hodge, 2019), psychological states (Kim and Cruz, 2016; Malloy and Kavussanu, 2021) and sports performance of players (Cervelló et al., 2007; Gillet et al., 2010). In contrast, unsuccessful implementation of these roles may lead to negative outcomes on facets of athletic participation (Isoard-Gautheur et al., 2016; Cheval et al., 2017). The complexities of how leadership, particularly coaches' leadership, affect athletes' overall state and performance have been constantly intrigued scholars for decades, and in turn, have shown tremendous growth in published studies related to this topic (Gilbert and Trudel, 2004; Sheehy et al., 2018; Gan and Yusof, 2020; Michalski and Lee, 2021).

When numerous studies exist in the literature, it is common for scholars to consolidate findings of a certain topic/field using different approaches such as systematic literature review or

meta-analysis. The former summarizes the results from previous studies on a specific topic using a qualitative approach while the latter consolidates empirical data of individual studies to estimate the effect size of the relationship between variables (Creswell, 2014). Synthesizing the findings from either approaches can help scholars to have a better understanding of the current knowledge, determine the impact of a phenomenon/intervention, identify issues, gaps, and trends, and provide a reference point for future research (Grant and Booth, 2009; Creswell, 2014). In the coach leadership area, several scholars have attempted to summarize existing findings employing either systematic literature review (Gilbert and Trudel, 2004; Sheehy et al., 2018; Mills and Clements, 2021) or meta-analysis (Kim and Cruz, 2016; Kim and Cruz, 2022). The findings from the literature review showed that existing studies were mostly focused on the impact of coaches, particularly their behaviors, on athletes' performance, psychological development, and well-being. It was also found that coach-related studies were aimed to develop, evaluate, or use measurement tools related to examining sources and dimensions of coaching behaviors (Gilbert and Trudel, 2004; Sheehy et al., 2018; Mills and Clements, 2021). On the other hand, results from the meta-analysis by Kim and Cruz (2016) revealed that coach leadership's effects on cohesion and athletic satisfaction were moderate and large, respectively, and with gender as a moderating factor for these relationships. Findings also showed that training and instruction had the highest contribution for the relationships between coach leadership and cohesion and satisfaction. In a recent meta-analysis that examined the relationships between coach transformational leadership and player satisfaction and commitment (Kim and Cruz, 2022), results revealed that both satisfaction and commitment of players were moderately affected by the transformational leadership behaviors of their coaches, particularly coaches who displayed charismatic behaviors. Moreover, female players tended to report higher satisfaction and commitment than male players when coaches display more transformational leadership. Overall, the findings presented the significant topics related to coach leadership and the magnitude of the relationships between coach leadership and athlete-related outcomes.

Aside from these two common review approaches, another method that is recently attracting researchers to employ in their research when reviewing data from various studies is bibliometric analysis. Bibliometric analysis is a rigorous procedure to evaluate large amount of scientific information in order to provide meaningful interpretation about a certain research topic or a research field's state of intellectual structure and future trends (Donthu et al., 2021). Bibliometric analysis is found to be advantageous when summarizing dataset from numerous studies in the existing literature because it employs quantitative technique on relevant research components (e.g., authors, keywords, word content, and journals) thereby avoiding bias. Moreover, with the development of software technology related to bibliometric analysis, quantitatively extracting and examining the contributions of relevant research components (i.e., publication-related metrics) and the structural relationships among these research components (i.e., co-word analysis) are now faster and more convenient compared with the conventional manual approach of literature review (Sotiriadou et al., 2014). Hence, researchers are now beginning to utilize bibliometric analysis as an alternative and novel methodology to understand the existing knowledge in the literature, to identify gaps and future trends about a research topic, and to explore the intellectual structures of a certain research field/topic when working on large amount of scientific information available in the literature.

While the application of bibliometric analysis when conducting review study has been growing in various research fields such as business (Liesch et al., 2011; Donthu et al., 2020; Kumar et al., 2021), tourism (Cheng and Edwards, 2019; Yu et al., 2021; Goh and Wilk, 2022), and education (Zawacki-Richter et al., 2017; Hyndman and Pill, 2018), this methodology in reviewing published studies is still relatively uncommon in the area of sport and exercise psychology. Only few reviews have been conducted that applied bibliometric analysis. Khoo et al. (2021) summarized nine sport and exercise psychology journals from Asia and South Pacific region. They found that highly cited authors were mostly affiliated with universities from Australia, New Zealand and Singapore and many of the authors tended to collaborate with other scholars within and outside the region. Lindahl et al. (2015) examined the trends and intellectual base of sport and exercise psychology using bibliometric analysis. The findings provided a "bird's eye view" of the evolution, performance contributions of research components, and relationships among the intellectual structures of sport and exercise psychology. Taş et al. (2021) described the characteristics of articles published in sports and exercise psychology journals classified in each quartile of Web of Science. They reported that United Kingdom, United States, and Canada were the most productive countries in the field of sports and exercise psychology. They also found relationships between number of citations and lengths of title, abstract and introductions and numbers of country affiliations and references. However, these bibliometric reviews are still limited in terms of the kind of bibliometric analysis technique employed. Khoo et al. (2021) and Taş et al. (2021) mostly focused on the publication-related metrics such as trends, authors, citations, and countries/universities with not much information about the actual content of the studies included. Other bibliometric analysis techniques that emphasize other unit of analysis, such as written content (e.g., abstract and full text words) of publications, may provide different perspective when exploring the semantic and thematic relationships of words with one another. Therefore, examining words as a focal unit of the bibliometric analysis would be a noteworthy technique in shedding more light about the existing or future relationships among word topics within a research domain (Donthu et al., 2021). On the other hand, previous bibliometric review (Lindahl et al., 2015; Taş et al., 2021) in terms of time duration was rather short thereby restricting the findings (e.g., 3 years). Furthermore, while diverse themes were presented when it comes to the research topics in sport and exercise psychology (Lindahl et al., 2015), specific details related to these topics are fairly lacking. In the Lindahl et al. (2015) study for example, within the leadership and social influences theme, only the number of articles and general keywords were reported related to coaches. There were also few studies that represented this topic. It would be worthwhile therefore to expand the search about coach leadership similar to previous study (Khoo et al., 2021) and extensively examine the written content of published articles using bibliometric analysis due to its ability to process large amount of dataset. The findings from this novel approach in reviewing existing studies not only provide different insights into understanding the current body of knowledge about coaches leadership within the sports psychology domain but also identify the structural relationships among the relevant research components in this area.

Therefore, the objective of this study was to summarize and examine published articles concerning sports leadership within the sport psychology domain over the last 30 years using bibliometric analysis as a review methodology. We considered a novel bibliometric analysis technique that centered on the written content of the publications (full text) as unit of analysis in order to explore the

intellectual base, particularly the structural relationships among relevant research components about coach leadership. As such, the finding does not merely provide a general overview of sport leadership by describing the general publication-related metrics such as total publications, authors, and affiliations but rather offers a different viewpoint of sports leadership by exploring themes and concepts that would emerge from published articles within the sports psychology domain and therefore present a groundwork for comparisons between current and future reviews.

2. Methodology

2.1. Published articles identification, screening, eligibility, and data extraction

The primary data sources for this bibliometric review study were the journals contributing to the focal areas of sports psychology. Due to the large volume of data and reliability of our potential findings, it was necessary to limit ourselves within the list of journals in which the academic society of sports psychology believes those composed of both validity and reliability evidence. The data sources for this analysis were defined and selected from the WoS Master Journal List by Clarivate Analytics (formerly the Institute of Scientific Information by Thomson Reuters since 1956; Clarivate, 2021). WoS is a collection of reputable global citation databases over 250 disciplines and all regions (Clarivate, 2021). The WoS list provides detailed information on scope notes, definitions, and the most important impact factor score of selected journals by index promptly (Clarivate, 2021). To assist us in determining the core journals, we considered the selection criteria followed by previous authors (Lindahl et al., 2015). The criteria included impact factor, relevance to the field of sport psychology, and conformity between the authors conducting the research. This journal selection protocol led to four journals: (1) The Sport Psychologist (SP), (2) Journal of Applied Sport Psychology (JASP), (3) International Journal of Sport Exercise Psychology (IJSEP), and (4) Psychology of Sport Exercise (PSE). In addition to the aforementioned criteria, these journals were chosen because SP is one of the earliest journals dedicated to sport psychology, while JASP, IJSEP, and PSE are the official publications of the Association for Applied Sport Psychology, International Society of Sport Psychology, and European Federation of Sport Psychology, respectively. These organizations are the most widely recognized by researchers and practitioners in sports psychology.

From each journal's official website, the authors independently visited and searched the document archives using keywords such as "coach," "coaching," and "leadership." Only the leadership behavior of coaches was considered a significant subject matter of this study. Published articles identified by the journal's electronic search were screened based on the titles with the keywords previously mentioned.

During the selection process, articles were excluded if (1) not relevant to the psychological aspects of coaching and leadership for athletes at different levels of participation, (2) contained only a fractional amount of relevant content to coaching and leadership issues, (3) not published within the specified period between 1990 and 2021, and (4) book review, conference proceedings, and research reports. Next, full-text copies of the articles were retrieved *via* downloading from the journal's site, university library, or academic full-text databases. The primary authors meticulously reviewed and categorized the text data into an Excel spreadsheet for details of the selected articles for final data analysis. Any disagreements related to the selection criteria were discussed and resolved with the assistance of an external referee with expertise in similar research field. Three articles were excluded because of duplications. Specific data from the articles that met the review criteria were categorized based on: (1) number of publications, (2) county affiliation of authors, and type of research design. The entire process of the article search until data extraction was conducted in August 2021 (see Figure 1).

2.2. Data analysis

Text data from all eligible articles were extracted and then transformed into PDF format to be processed using the Leximancer version 5.0 (Leximancer Pty Ltd.) text mining tool. Leximancer is a kind of bibliometric software that processes textual documents into words, concepts, and themes and presents them as a map of interconnected words together with their level of connections (Crofts and Bisman, 2010).

Inter-coder reliability is often an issue when conducting content analysis. However, because text sources and their segments are automatically and objectively coded and analyzed using this CAQDAS

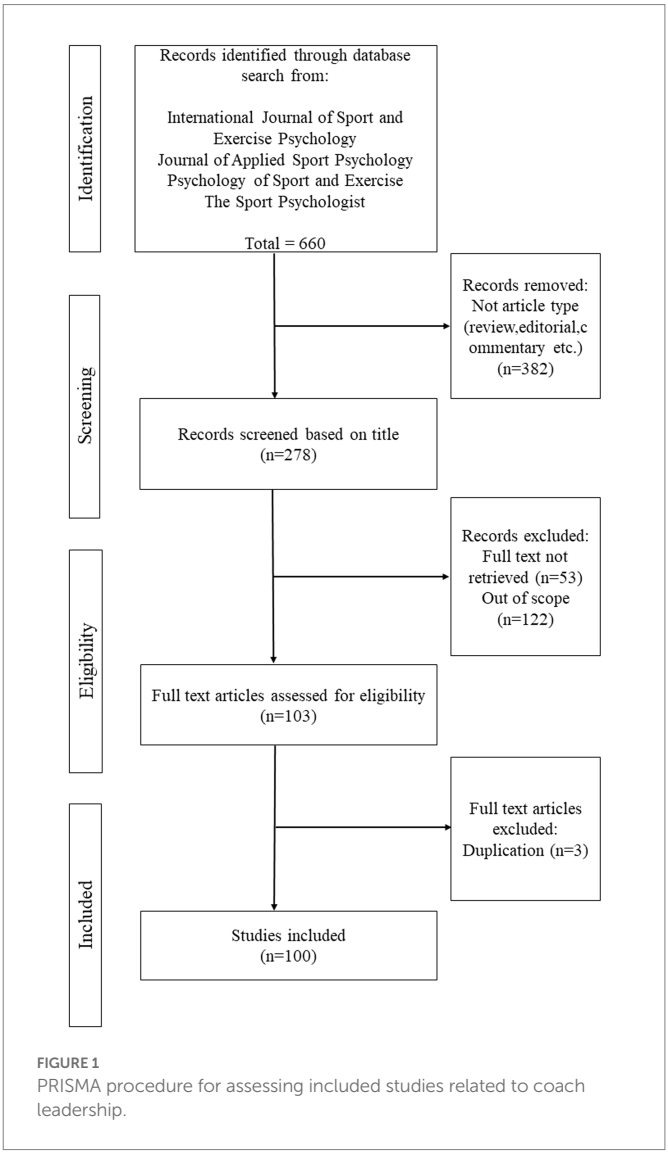

FIGURE 1
PRISMA procedure for assessing included studies related to coach leadership.

tool, researcher bias coder subjectivity may no longer be considered an issue (Smith and Humphreys, 2006; Sotiriadou et al., 2014).

After processing the extracted data, Leximancer then generate a thesaurus of words and phrases (i.e., themes), which are then transformed into concepts based on contextual similarities based on groups of concepts (Lemon and Hayes, 2020). This text data-mining technique employs semantic and relational extraction on different strata of text datasets (Froggatt, 2001). In other words, the concept and theme-mapping algorithm is based on the hierarchy of appearance and relational extraction derived from Bayesian decision theory (Stemler, 2015). The algorithm automatically identifies words and phrases that co-occur and detects significant networks and semantic patterns among concepts through non-linear dynamics and machine learning methods (McDonald and Kelly, 2020).

Next, a visual display called a "conceptual map" (i.e., colored and grouped bubbles) is automatically generated. This map is a graphic representation depicting the thematic and conceptual relationships of any given text data. The most unique feature of this analytic tool is its ability to generate conceptual maps on the way of developing meaningful outputs. This feature makes this analytic tool superior to traditional qualitative analysis methods in terms of human bias and the ability to process large volumes of data (Sotiriadou et al., 2014). The following are the important features of the conceptual map of Leximancer: (1) colors, denoting the level of importance of each theme (i.e., red indicates the highest level of connectivity while purple is the least connected theme), and (2) size of the theme, denoting the level of clustering appearance of a concept with other concepts within single text mining analysis (Kim, 2021). That is, group clusters of concepts are called "themes" varying from hot colors (red, orange) to cool colors (blue, green).

The Leximancer program generates a dashboard report containing the statistical results of text mining analysis. More specifically, the report is composed of (1) "hit count," which is a frequency indicator of a word-like concept presented in a dataset; (2) "relevance," which refers to the co-occurrence of word-like concepts estimated as a percentile rate; and (3) "connectivity," which is the sum of all the text co-occurrence counts of any given concept with every other concept on the concept map (Leximancer user guide, release 5.0). The report is a quantitative overview of Leximancer's concept map and presents the thematical and conceptual similarities and differences among the sourced text data. This tool has been adopted by researchers across a variety of disciplines including education (Zawacki-Richter and Naidu, 2016), health (Cretchley et al., 2010a), management/marketing (Anagnostopoulos and Bason, 2015; Kim, 2021), and psychology (Cretchley et al., 2010b; Choi and Kim, 2021).

3. Results

3.1. Research trend

From the four selected sports psychology journals, 100 articles (IJSEP = 11, JASP = 35, PSE = 43, TSP = 11) have been published in relation to coach leadership in sports over the last 30 years. The number of publications has increased from 2001 onwards in JASP and PSE journals, with more than 10 recorded articles within the 2016–2021 period. On the other hand, the attention of IJSEP and SP in publishing articles about coach leadership was relatively low compared with JASP and PSE despite an increase in publication rate that started from the 2011–2015 period (see Figure 2 Top).

In terms of the research design of published studies from all journals, 76% of all publications were quantitative research, with the majority of articles coming from PSE (35) followed by JASP (26), IJSEP (9) and SP (6). JASP had the highest number of qualitative studies (9), followed by PSE (8), SP (5) while IJSEP had the least number of qualitative studies published (2).

3.2. Leading countries publishing coach leadership

The country affiliations of authors in all published articles were identified and tabulated to determine the countries committed to examining coach leadership in sports. Overall, the United States, followed by Canada, the United Kingdom, and Belgium were the top countries involved in the area of coach leadership. Interestingly, the leading countries that contributed published articles on coach leadership varied depending on each journal. The United Kingdom and Canada were the top contributors to publish articles in IJSEP and PSE journals, respectively. The United States had the most publications in both JASP and SP journals. (See Figure 2 bottom).

3.3. Overall text mining analysis

Based on the overall text mining analysis from the published articles related to coach leadership in sports, 9 key themes were generated with hit count and connectivity scores ranging from 52 to 540 and 425 to 8,947, respectively. 20 core concepts emerged with textual association relevance ranging from 10 to 100%. See Figure 3.

3.3.1. Specific journal text mining analysis

In the IJSEP, 10 key themes were generated with hit count and connectivity scores ranging from 2 to 46 and 7 to 716, respectively. 21 core concepts emerged with textual association relevance ranging from 9 to 100%. See Figure 4 Top left.

In the JASP, 11 key themes were generated with hit count and connectivity scores ranging from 7 to 136 and 28 to 1799, respectively. 21 core concepts emerged with textual association relevance ranging from 10 to 100%. See Figure 4 Top right.

In the journal of PSE, 16 key themes were generated with hit count and connectivity scores ranging from 14 to 271 and 82 to 4,521, respectively. 20 core concepts emerged with textual association relevance ranging from 11 to 100%. See Figure 4 Bottom left.

In the journal of SP, 10 key themes were generated with hit count and connectivity scores ranging from 3 to 49 and 17 to 939, respectively. 20 core concepts emerged with textual association relevance ranging from 11 to 100%. See Figure 4 Bottom right.

4. Discussion

This study examined published articles concerning sports leadership within the sport psychology domain over the last 30 years using bibliometric analysis with a technique which centered on the written content of the publications as unit of analysis in order to explore the structural relationships among relevant research components about coach leadership. According to the trend analysis of coach leadership, the overall result showed that published articles related to coach

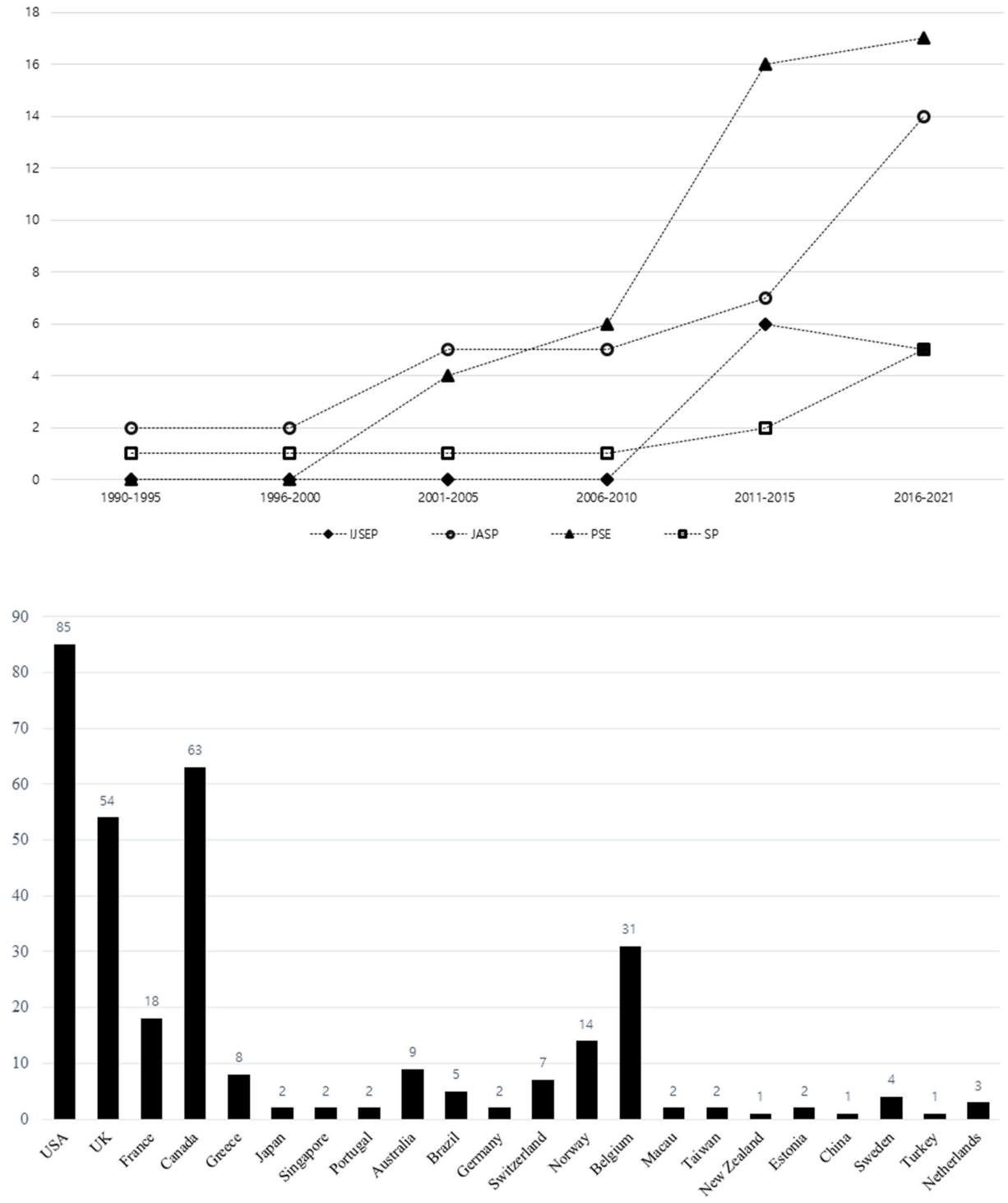

FIGURE 2
Research trend of coach leadership based on selected journals.

leadership have steadily increased since the beginning of 2000. From 10 articles published from 2001 to 2005, the number of publications quadrupled in the 2016–2021 period. This finding corroborates previous literature reviews that found an increasing growth rate in published articles on leadership in sports (Sheehy et al., 2018; Gan and Yusof, 2020). Among the journals that published articles on coach leadership, PSE had the highest number of publications. This is a noteworthy finding considering that the number of publication volumes per year is identical to IJSEP and JASP, with six volumes each, while SP has four volumes per year. This result, therefore, suggests that PSE has taken more attention to publishing submitted manuscripts concerning coach leadership studies compared to other journals.

The current results confirmed previous studies that found the United States, Canada, and the United Kingdom to be the top contributors of research in sports leadership (Sheehy et al., 2018; Gan and Yusof, 2020), as well as sports leadership articles focused on

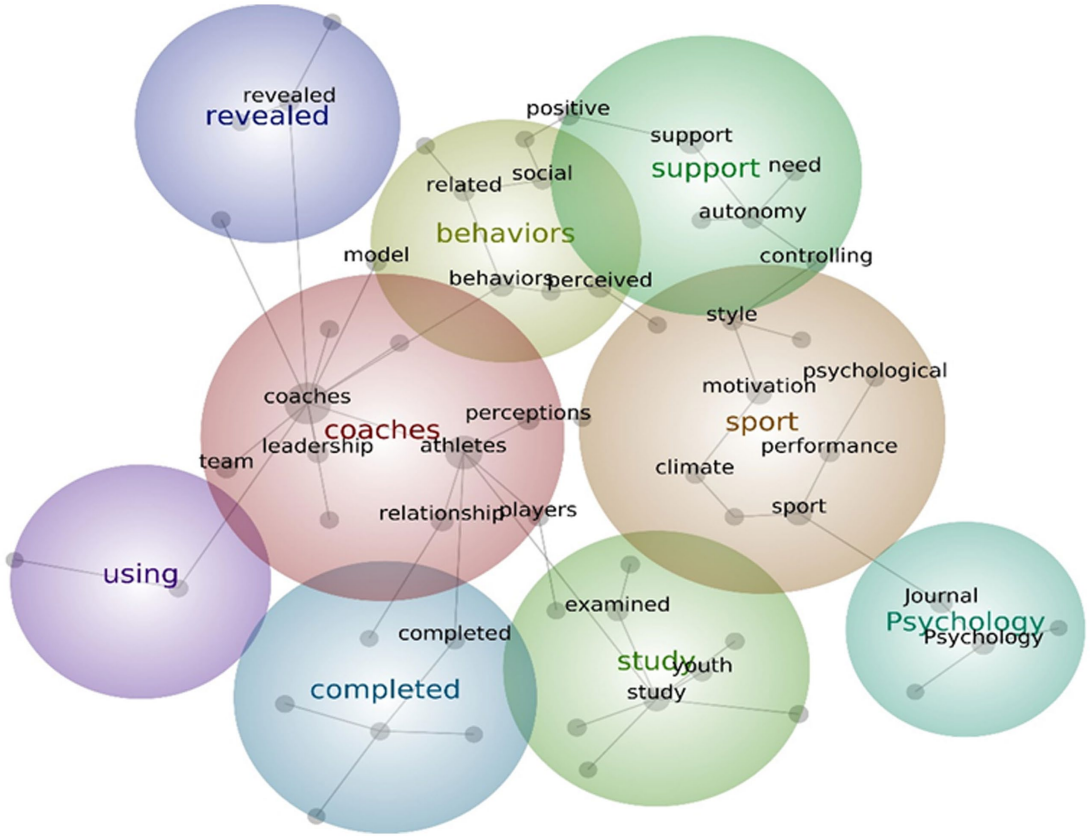

FIGURE 3
Overall concept map of coach leadership studies.

quantitative research (Gilbert and Trudel., 2004; Sheehy et al., 2018). An interesting result in this study that was not identified from previous reviews is the dominance of a particular country (or at least the authors affiliated with that country) in every journal. The United States had the highest number of publications in JASP and SP, while the United Kingdom and Canada dominated IJSEP and PSE in terms of publishing coach leadership studies, respectively. This result might be attributed to the country origin of the academic association of the journals where the authors were affiliated (i.e., JASP = United States; IJSEP = United Kingdom). The inclusion criteria of studies only written in English is another potential reason for the large number of authors from English speaking countries. Other authors who are not from English-speaking countries could have published their researches in other journals or journals that are written in their local language. Hence, only few authors affiliated from other nations are tallied, especially from Asia. However, authors affiliated with countries in Middle East and Africa are absent in this present review. Therefore, to further trace and account the authors who are conducting research in coach leadership, the journal scope should be expanded to journals publishing in both English and native languages.

4.1. Coach leadership themes and concepts

Across all articles included in this study, the overall results using Leximancer text analysis showed 20 core concepts that were found to be mostly associated with coach leadership and with coaches and athletes to have the highest connectivity with coach leadership. This result is not surprising considering the definition of leadership that consists of a leader and a member/follower (Northouse, 2015), which in this case, the coach and athletes, respectively.

Semantically related concepts were grouped to create key themes (colored circles) and ranked ordered by Leximancer. The most prominent key theme *coaches* with athletes, relationships, perceptions, leadership, and players as concepts within this key theme pertain to the study topics related to coach leadership. These study topics include coach-athlete relationship as well as perceptions of players about their coaches' leadership behaviors, since this theme is also linked to theme 3 (behavior). This result support previous findings that published articles focused on coaching research frequently investigated behaviors and perceptions/thoughts of coaches (Sheehy et al., 2018). Moreover, the concept *team* within the *coach* key theme seems to indicate its importance in the area of coach leadership in sport, particularly that players or coaches in team sports are the study participants commonly examined in this topic.

The second key theme *sport* reflects sport-related outcomes that can be affected by the leadership style of coaches, such as motivation, sports climate, performance, and psychological states. Furthermore, *sport* key theme is closely linked to key theme *study* with concepts *examined* and *youth*, suggesting that published studies are mostly dedicated to examining these sport-related outcomes in youth players.

The third key theme *behavior* and the related concepts within it suggest the kind of support and interpersonal behaviors related to coaches perceived by players. This notion is corroborated by its link with *support* key themes with concepts such as *autonomy* and *controlling*, indicating types of coach leadership style.

FIGURE 4
Concept maps for each journal.

Based on the findings from data analysis, it is important to note that no specific name(s) emerged as a core concept or theme. While Leximancer as a data analysis tool can also identify names of people as concepts, no name-like concepts were generated. This implies that no specific scholar(s) are strongly connected in the area of coach leadership. However, this is open for further investigation since Leximancer's use is to explore written (word) contents of the publication but does not cover author names as data requirements in order to conduct co-author analysis. Likewise, relationships of journals, citations, and references were not explored due to the analytical tool's operational constraints. Therefore, the use of other bibliometric technique to examine relationships among relevant publication-related metrics is suggested to complement the limitations of a bibliometric analysis focused only on word contents. Combining different bibliometric techniques in analyzing relevant data of published studies when conducting bibliometric review can provide further insights about the structural relationships among research constituents concerning coach leadership.

4.2. Sport psychology journals' coach leadership themes and concepts

The first key theme that emerged from studies in the IJSEP is *coaches*. In addition, related concepts within this key theme reveal topics about the leadership of coaches, particularly their behaviors in sports settings. The connectedness of this key theme to *relationship* suggests that studies in this journal focused more on the relationships between coach leadership and athletes' sport outcomes. This notion is somewhat supported by concept *motivation* as part of the relevant concepts under *coaches*' key theme, indicating how the coach can impact athletes' motivation.

The key theme *relationship* linking to the key theme *completed* implies the methodological approach of data collection *via* questionnaires. This finding reflects previous results that the majority of published articles used questionnaires when examining coach leadership and its related outcomes (Gilbert and Trudel, 2004).

Relevant concepts such as *differences* and *youth*, are also connected with the *goal, life*, and *PYD* (positive youth development) concepts, indicating authors who published in IJSEP conducted comparative studies about youth sports players as well as emphasized the role of coaches not only in the improvement of young players' sports performance but also on the development of their well-being. This notion highlights the importance of coaches in fostering positive values and life skills in athletes *via* their leadership behaviors. These leadership behaviors would be deliberately teaching positive and non-violent communication skills and respectful behaviors, encouraging active participation and effort during training and competition, providing opportunities to independently work on personal goals and progress,

delegating leadership roles among players in the team, and challenging athletes to apply these personal and social life skills to other aspects of their lives aside from sports (Carreres-Ponsoda et al., 2021). In this way, young athletes who learn and apply these values and personal and social skills are not only better equipped to quickly adapt to the demands and stressors of competitive sports in achieving performance excellence but are also well prepared to transfer these positive competencies, attitudes, and behaviors to other parts of their non-sporting lives. This view is also in line with the role of coaches in facilitating positive youth development in sports (Santos et al., 2016).

Interestingly, the distance between the concept/theme *punishment* is relatively far from the main themes in the concept map despite its link with *athletes* and *behaviors* themes. This finding indicates a potential relationship of *punishment* with *athletes* and *behavior* themes but the connection is rather weak. Upon further exploration, *punishment* was depicted as verbal punishment perceived by players as an acceptable behavior. However, more study is needed to validate this finding in order to further understand how types of punishments can affect players' sport-related outcomes given that punishment has been reported as an acceptable method to maintain or create order and stability in sports (Seifried, 2008).

The first key theme that emerged from published studies in the JASP related to coach leadership is *athletes*. Concepts within this theme suggest that articles given attention by this journal are clustered mostly on examining coach behaviors and how they relate to athletes' motivation, competence, and commitment. Other concepts such as *model* and *female* within this key theme reflect how authors exemplify theoretical models in understanding coach-athlete relationships, as well as recognizing women as important sport participants, and how coaches' behaviors influence their own behaviors and psychological states.

Empowering young girls and women and achieving gender equality is one of the United Nations' Sustainable Development Goals, and sport is recognized as a relevant contributor to realizing this goal (Lemke, 2021). However, despite the substantial growth of women's participation in sports over the last several decades (International Olympic Committee, 2018a; Nielsen, 2020), there is still a gap in terms of gender equality and participation in sports between men and women (International Olympic Committee, 2018b). Accordingly, researchers interested in understanding this phenomenon have conducted studies focusing on women in sports in general (Senne, 2016; International Olympic Committee, 2018b), while others explored specific topics related to women in sports such as coach leadership and its association with performance and psychological outcomes in female athletes (Vealey et al., 1998; Alexander et al., 2020). Hence, to further place sport as a catalyst for promoting and achieving sustainability goals, particularly gender equality and women empowerment, stated in the 2030 Agenda for Sustainable Development (Dudfield, 2019), more sport studies related to this topic are warranted.

Key themes *revealed* and *leadership* with concepts such as positive, support, perceived, effect, and theory imply that published articles in JASP also analyzed perceived leadership styles and explained the results following a certain theory. This result agrees with the previous report (Sheehy et al., 2018) that one of the intended impacts of leadership studies was to contribute to the development of certain theories.

The key theme *study* with concepts that include players, soccer, youth, and males is an interesting result suggesting that coach leadership studies published in JASP included study participants composed of mostly male youth players participating in soccer. This finding provides additional information about the characteristics of participants when reviewing coach leadership studies in which previous literature reviews were not able to identify (Sheehy et al., 2018; Gan and Yusof, 2020).

Further, the *elite, psychology*, and *Athletes* concepts are relatively distant from the other core themes suggesting these words have weak relationships with coach leadership in this particular journal. This finding underscores how limited elite athletes in this journal are investigated and therefore warrants more studies to further understand the status of elite athletes and their relationships with their coaches.

Results from the text mining analysis of published articles from PSE revealed key themes of *coaches, support, sport*, and *study*. The *coaches* key theme indicates the motivational climate created by a coach and its possible consequences on athletes, such as motivation. The *support* key theme denotes the interpersonal behaviors of the coach. The *sport* key theme suggests the perceived behaviors of coaches. Interestingly, the *study* key theme implies the related theoretical models applied in the studies. Moreover, based on the concept map, the key themes and concepts are closely linked to one another, reflecting that studies published in PSE mostly examined behaviors of coaches, such as controlling and autonomy support, following a theoretical model by probing participants' perceptions about their coaches.

Furthermore, connections among *players, sports, youth, athletes*, and *team* concepts suggest that participants in these studies predominantly comprised young male athletes in team sports. This result is not surprising considering that sports participation rate is often higher in young males and in team sports (Hyde et al., 2020; Eime et al., 2021). It is also important to note that key male and seasonal themes exist in the concept map. However, they are fairly distinct and have low connectivity with other key themes, suggesting the prevalence of coach leadership studies that examined an exclusive set of participants and/or in a particular sporting season but on rare occasions.

Based on the text mining analysis of published articles in SP, the results revealed that the first key theme *coaches* is about coaches' characteristics and leadership style. The second key theme, *behaviors*, pertains to different behaviors that may often be displayed by coaches. The third key theme, *leadership*, is an outcome variable that may relate to leadership. These prominent key themes, with their relevant concepts linked together, denote studies published in this journal that generally focus on the relationship between leadership style and behaviors of coaches and psychological outcomes such as cohesion.

One interesting finding was the emergence of *interviews* as a key theme. Although considered a less prominent key theme (away from the main key themes and concepts), its link to the *satisfaction* key theme implies how data were collected and what topic was examined. This result supports Gilbert and Trudel (2004), who reported interviews as the 2nd prevalent method of data collection in coaching studies and further verified by the lack of disparity between the number of quantitative and qualitative publications found in this journal. However, it is suggested that more coach leadership studies be conducted using qualitative approaches, or better yet, explore this topic using mixed-method approaches so that more complete insights are generated about the topic compared with a single methodological approach (Creswell, 2014).

4.3. Limitations and future directions

The present study not only contributes to the body of knowledge in coach leadership as an area of study within the sports psychology domain but also provides a novel approach for extracting and analyzing information from both the entire literature and each journal's published

articles. Using a bibliometric methodology and a more stringent and systematic technique in examining text documents, we were able to identify concepts and themes and their semantic relationships related to coach leadership not previously determined by previous bibliometric reviews. To obtain more valuable insights and further understand coach leadership in sports, we encourage other researchers to continue examining this research topic not only from a general perspective but from a more detailed outlook by utilizing text mining tools to facilitate the systematic quantification of information-rich research articles in a more organized and well-defined concepts and themes that are more logical and comprehensible to decipher. Accordingly, acquiring detailed and comprehensible concepts and ideas about coach leadership and their associated outcomes can lead to better leadership and coaching practices that are sustainable for all sport participants.

This review has also some limitations. Since only articles from the four selected journals were included, data from other sports psychology journals deemed relevant to coach leadership were not assessed. Hence, a more extensive database of journals within the sports psychology domain is recommended for future studies. Identifying potential studies from other databases may help establish a better generalization of the findings. The current study mainly focused on analyzing themes and concepts related to the leadership of (main) coaches. Future researchers may examine the semantic data of other sports leaders, such as assistant coaches or team captains, to offer more and fresher perspectives related to sport leadership.

4.4. Conclusion

To conclude, the findings show that coach leadership studies generally focus on behaviors and perceptions related to the coach. Second, it highlights that published studies emphasize uncovering possible relationships between leadership and psychological outcomes. Third, the results underscore that each journal has a similar but distinct rationale when publishing papers about coach leadership. Fourth, the findings identify potential variables for future studies related to coach leadership by distinguishing isolated themes or concepts from the concept map generated by the text analytical tool Leximancer. Finally, the present study showcases the applicability of bibliometric analysis as an alternative methodology to review a research topic with large quantities of written content.

Author contributions

AC and H-DK conceptualized the research project and contributed to the writing of the manuscript (from the initial draft to the final manuscript). H-DK analyzed the data. All authors contributed to the article and approved the submitted version.

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.2023.1135243/full#supplementary-material

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Corrigendum: A bibliometric review of coach leadership studies

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The mediator role of communication skill in the relationship between empathy, team cohesion, and competition performance in curlers

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Understanding the psycho-social factors such as communication, empathy, cohesion, etc., that affect successful athletic performance is a high priority and primary focus for applied sports psychology. Detailed examination of the athletes' psycho-social characteristics is essential in revealing which processes play an active role in achieving optimum performance. Developing these features of the athlete can contribute to coordinating the team, sharing tasks, increasing motivation, preparing team members for a change, and improving performance. For this purpose, the mediating role of communication skills in the relationship between empathy, team cohesion, and competition performance was examined in a sample of 241 curlers competing in 69 teams in the Turkish Curling League in the 2021–2022 season. During the data collection process, Personal Information Form, Empathic Tendency Scale, Scale for Effective Communication in Team Sport, and Group Environment Questionnaire were used. Competition performance was calculated by giving 1 point for each match won by the teams in the competitions in which the single-circuit round-robin system is applied. Structural equation modeling was used in data analysis to determine the direct and indirect predictive effects between variables. The study showed that empathy and team cohesion predict competition performance through communication skills, and communication skills fully mediate this relationship. Based on the research results, it was evaluated that communication skills have a substantial effect on the competitive performance of athletes, and this finding was discussed in the context of the literature.

KEYWORDS

curling, performance, team cohesion, empathy, communication skill

1. Introduction

In parallel with the development of sports sciences, the expectation of the highest level of performance from competitive athletes is increasing (Tokdemir, 2011). Athletic performance is the execution of certain physical routines or procedures by someone trained or skilled in physical activity influenced by a combination of physiological, psychological, and socio-cultural factors (Fukuda, 2019). The level of the importance of these factors may differ according to sports branches (Bayraktar and Kurtoğlu, 2004). Since the competition's success in individual sports depends only on the athlete's performance, physical and physiological parameters seem to be the key to success.

Psychological processes such as team cohesion, communication skills, and empathy are more important in team sports (Kajbafnezhad et al., 2011; Mujika et al., 2018).

The role of psychological skills in increasing performance in sports branches where social, cognitive, and psychological factors are important is one of the most exciting topics for researchers (Birrer and Morgan, 2010; Siekańska et al., 2021). Research in sports settings has provided evidence that psychological skills facilitate athletic performance for both team and individual athletes (Thelwell et al., 2006; Birrer and Morgan, 2010; Beauchamp et al., 2012; Birrer et al., 2012; Hardy et al., 2018). Studies show that communication skills, team cohesion, and empathy are psychological parameters that positively affect competition performance (Sevdalis and Raab, 2014; Cranmer et al., 2020).

The empathy is defined as the process of putting oneself in the place of the other person and looking at events from his perspective, feeling and understanding the feelings and thoughts of the other person correctly, and conveying this situation to him (Dökmen, 2004). Empathy is the basic ability that enables people to notice emotions, establish and maintain relationships with others (Decety and Jackson, 2004). Lack of empathy may be related not only to difficulties in understanding other people's emotions, but also to difficulties in understanding one's own emotions (Schipper and Petermann, 2013). This condition is associated with mood disorders, aggressive behavior, and communication disorders in humans (Lovett and Sheffield, 2007; Schipper and Petermann, 2013; Gandhi et al., 2021). The idea that empathy can affect an athlete's performance has only recently been discussed in the literature. Observing others during physical activity is almost inevitable and exists in settings from recreational physical activity to professional sports, which can affect individual or team performance (Behm and Carter, 2021). The action of observing others fatiguing or in pain due to exercise has been shown in recent studies to elicit a perceptual empathic response (Noakes, 2012; Xu et al., 2019; Yuksel et al., 2019; Astokorki et al., 2021). A more empathetic athlete may contribute to greater team cohesion and spirit, which could be a deciding factor for a coach when choosing between two similarly talented athletes (Behm and Carter, 2021). Remarkably, the athletes competing in team sports should have high levels of empathy to predict their teammates' reactions, understand the opponent's emotions, and make the right decision in a dynamically changing environment (Budnik-Przybylska et al., 2021). For this reason, empathy is one of the psychological keys to success in sports environments (Erdem, 2013; Sevdalis and Raab, 2014).

Another psychological factor affecting the competition performance of team athletes is team cohesion. Cohesion has been defined as a dynamic process reflected in a group's tendency to stay and stay together in pursuit of instrumental goals and/or the satisfaction of members' emotional needs (Worley et al., 2020). Cohesion, which is defined as an imaginary chain that binds team members together, is a dynamic process that reflects the tendency of a group to stick together and stay together within the framework of common goals (State-Davey, 2009). When we look at the characteristics of successful teams, it is seen that team members are socially close to each other, and their communication is strong (Durdubaş, 2013). The importance of team cohesion becomes more apparent in tasks requiring more group members' interaction, mutual monitoring, and dependence on each other (Öcal and Aydin, 2009). Many studies on cohesion have shown a positive relationship between team cohesion and team performance (Høigaard et al., 2006; Bell et al., 2019).

Effectiveness communication skills are among the most important ingredients contributing to performance enhancement and the personal growth of sport and exercise participants (Weinberg and Gould, 2019). In addition to affecting performance (Lausic et al., 2009), it is also related to other psychological factors, such as empathy and group cohesion, impacting performance (Carron et al., 2005). In empathy, communication skills are essential in transferring emotions to the other party (D'souza et al., 2020). In this context, interventions, including communication skills training, are applied to develop empathy in many different areas (Stepien and Baernstein, 2006). Effective communication is also associated with team cohesion. Effective communication within the team contributes to the sharing of similar personal stories by the athletes, thereby creating increased awareness and a sense of togetherness (Carron et al., 2002). This situation increases team cohesion by enabling the athletes to cling to each other more (Beauchamp and Eys, 2014). Due to its features, effective communication can mediate the effect of group cohesion and empathy on competitive performance in team sports (Rapisarda, 2002).

Curling is one of the most appropriate branches that can reveal the mediating role of effective communication in the effect of group cohesion and empathy on competition performance because all competitions are played in a single arena and at the same time (Federation, 2020) so that athletes must thoroughly and quickly perceive what their teammates say (the skip's command to sweep, which shot should be played, and what tactics they apply etc.). For example, when watching a curling match, it can be seen that skips communicate by developing different codes (Woooov: No-sweep, Yeap: Sweep) when they need to give sweep or no-sweep commands to their teammates. During the competition, curlers can communicate with gestures, facial expressions, and verbal communication (Alaeddinoğlu et al., 2022). For example, skips can indicate rock speed with various moves to their teammates. When skip wants a guard shot, he takes the broom between his hands and raises it above his head, and when he wants a take-out shot, he puts his hand on his belly, shoulder, or head. Team members who can better communicate verbally and physically during the game provide more information quickly. Teams that can communicate well are fine with using time in the game (Federation, 2020).

The sport of curling contains more cognitive and psychological skills due to its structure. Curling is the only sport where the route of the stone thrown toward the target can be changed (Buckingham et al., 2006). After the delivery, it is a team sport consisting of athletes who aim to place the stones as close to the target as possible. It is seen that successful teams in the sport of curling consist of players who have played together for many years (Weeks, 2019). Since curling team members consisting of five athletes must train together constantly to ensure consistency in their shots, the athletes must establish close relationships with a limited number of people (Collins and Durand-Bush, 2010, 2016). As a result, athletes competing in curling and other team sports should develop a tactical strategy, make correct and fast decisions, support each other, cope with stress and act in sync in competition as one body. Examining variables such as empathy, communication skills, and team cohesion, which have been scientifically proven to affect individual performance, within the framework of a mediated model in the curling branch will guide researchers and coaches working in this field. In this context, this study aims to examine the mediating role of communication skills in the effect of curlers' empathy and team cohesion on competition success. In this context, this study aims to examine the mediating role of communication skills in the effect of curlers' empathy and team cohesion on competition success.

2. Methods

2.1. Research model

This study, designed in a correlational survey model, examined the relationships between competition performance, empathy, team cohesion, and communication skills in curlers. In this context, Structural Equation Modeling (SEM) was used to explain the predictive correlations between variables (Collier, 2020).

2.2. Participants

A total of 241 athletes participated 112 males (46.6%) and 129 females (53.5%) from 69 teams competing in the Turkish Curling League in the 2021–2022 season in the study. Ages of the athletes ranged from 18 to 38 ($\bar{x}$=26.08 ± 6.81), between 1 and 11 years of licensed sports ($\bar{x}$=5.86 ± 2.82), and between 1 and 10 years of playing with teammates ($\bar{x}$ =3.48 ± 2.00). Other descriptive information about the athletes participating in the research is given in Table 1.

Since the collected data includes information about the team, such as intra-team communication and team cohesion, the participation of at least two athletes from each team was determined as the criterion for inclusion in the research.

2.3. Data collection tools

The data collection tools in the research consist of 5 parts: Personal Information Form, Empathic Tendency, Team Cohesion, Effective Communication Scale for Sports Teams, and Turkey Curling League competition (performance) scores for the 2021–2022 season.

2.3.1. Personal information form

In the personal information form prepared by the researcher, some items include the participants' gender, age, order, and position information in the team.

TABLE 1 Descriptive of the participants.

Variable	*n*	%
Gender		
Male	112	46.5
Female	129	53.5
Order		
Lead	56	23.2
Second	42	17.4
Third	79	32.8
Fourth	64	26.6
Position		
Skip	84	34.9
Vice	73	26.1
Front – end	94	39.0

2.3.2. Empathic tendency scale

The Empathic Tendency Scale developed by Dökmen (1988) was used to determine the empathy potential of the athletes participating in the study and the level of empathic behavior in daily life. The scale consists of 20 items prepared as a Likert-type scale. In the scale, there are questions to measure the empathic tendencies of the individual, such as "The problems of others concern me as if they were my problems," "My close friends often tell me about their problems," "When arguing with someone, sometimes my attention is focused on my answers rather than what they say." The scores of the scale items are "strongly agree = 5" and "strongly disagree = 1" and the possible scores are between 20 and 100. A high score means a high empathic tendency, and a low score means a low empathic tendency. The Empathic Tendency Scale was administered by Dökmen (1988) to a group of 70 students twice, 3 weeks apart. The reliability coefficient of the test repetition obtained from these two applications was found to be 0.82. The correlation coefficient between the scores the students got from the odd and even items of the scale with the split-half method is 0.81. For the validity study, the relationship between the Empathic Tendency Scale and the "Understanding Emotions" section of the Edwards Personality Preference Schedule was examined. A correlation of 0.68 was found (Çevik, 2017). In this study, the Cronbach Alpha reliability coefficient of the scale was found to be 0.934.

2.3.3. Scale for effective communication in team sport-SECTS

Scale for Effective Communication in Team Sport (SECTS), developed by Sullivan and Feltz (2003) and adapted into Turkish by Alkan (2009), was used in the study to determine the communication skill levels of athletes. SECTS is a 7-point Likert-type scale comprising 15 items measuring effective communication skills within a team. It has four sub-dimensions: Acceptance, Distinctiveness, Positive Conflict, and Negative Conflict. Acceptance is measured by three items and refers to interpersonal messages of support or evaluation (for example, we trust each other). Distinctiveness is measured by three items and includes these messages of a shared, overarching team identity (for example, we use aliases). Positive Conflict refers to a constructive, emotionally controlled discussion of interpersonal differences (for example, compromising with one another when we disagree). In contrast, Negative Conflict refers to disagreements expressed in a confrontational or destructive way (for example, we look each other in the face when we disagree). While these four dimensions vary widely within sports teams, they are related to team cohesion (Sullivan and Short, 2011) and performance (Ji and Yan, 2020). Confirmatory Factor Analysis (CFA) validated the scale with a sample of 251 athletes. The CFA showed that the model fit this sample strongly as well: x2/df = 1.97, CFI = 0.94, GFI = 0.91, GFI = 0.91, AGFI = 0.87, RMR = 0.03, and RMEA = 0.06. Goodness of fit indicates an excellent model, especially CFI, RMR, and RMSEA (Browne and Cudeck, 1992; Shi et al., 2019) and chi-square ratio (Mertler et al., 2021). The Cronbach Alpha values of the sub-dimensions of the original scale were Negative Conflict: 0.69, Acceptance: 0.86, Distinctiveness: 0.84, and Positive Conflict: 0.73.

2.3.4. Group environment questionnaire-GEQ

The "Group Environment Questionnaire" developed by Carron et al. (1985) and adapted into Turkish by Öcel and Aydin (2006), was used to determine the team cohesion levels of the participants. This 18-item instrument quantifies task and social cohesion, maintaining a distinction between individual-attraction-to-group, and group-integration

cohesion, distributed among four subscales. ATG-task cohesion quantifies how firmly each player is drawn to the group to satisfy individual task completion needs. ATG-social cohesion measures how strongly each player is attracted to the group to meet personal, social, and friendship needs. GI-task cohesion assesses the extent to which team members unite successfully to complete the common performance goal. GI-social cohesion quantifies perceptions of the degree to which the team bonds to satisfy social desires. The GEQ has been utilized extensively in the sports psychology literature as the instrument's psychometric properties are well established (Carron et al., 1985, 2005). Internal reliability for the ATG-task, ATG-social, GI-task, and GI-social cohesion subscales was 0.81, 0.75, 0.73, and 0.83, respectively (Carron and Ramsay, 1994).

2.4. Performance evaluation

Thirty-five male and 34 female teams participated in the 2021–2022 Turkey Curling League competitions according to the single round-robin system, and the teams received 1 point for each match they won, just like in the curling league. No points were awarded to teams for lost matches.

2.5. Procedure

The researchers met with all the athletes participating in the research (with each team separately) at Erzurum Curling Hall the day before the championship (on the last training day). After the data collection tools were introduced, the participants filled out the self-report scales. The performance scores used in the research were obtained from the Turkish Curling Federation web page. Before analyzing the research data, the researchers subjected it to a preliminary analysis to check whether it be missing or incorrect data. As a result, seven athletes, four females and three males, who filled out the form incorrectly, were excluded from the evaluation. In addition, two clubs that filled the data collection tools with a single athlete were excluded from the study.

2.6. Data analyses

Structural Equation Modeling (SEM) was used to test the research hypothesis. Structural equation modeling is a set of techniques in which latent structures can be examined through observable variables (Jöreskog and Sörbom, 1996). SEM was ideal for the correlational analysis targeted by the research, as it not only reveals the parameters of the correlation between latent variables but also allows the determination of error variances. The data obtained from the scales were transferred to electronic media using the SPSS package program. Descriptive statistics and correlation analysis of the variables were done with the SPSS 24.0 program, and the model test was done with the AMOS 24.0 program. "Maximum Likelihood (ML)" and "Covariance Matrix" were used as parameter estimation methods.

The analysis phase examined whether the data obtained primarily met the normality assumptions necessary for establishing the structural equation model. For this purpose, extreme values were examined using the z-test, kurtosis, and skewness coefficients. Mahalanobis distance coefficients were examined for the multi-directional outliers and the one-way outlier analysis. After analyzing the one-way and multi-directional extreme values, the normal distribution assumption was examined with the Kolmogorov–Smirnov normality test. The data set showed normal distribution characteristics. After testing the normal distribution assumptions, the variance inflation factor and auto-correlation were examined before the analysis. It was observed that there was no auto-correlation and that the variance inflation factors were within the required limit values. Afterward, it was decided that the data set was suitable for parametric statistical analysis, and the data analysis was started.

Mediated structural model testing consists of three main stages (Baron and Kenny, 1986). These steps are as follows; (i) Exogenous variables (empathy and team cohesion) should significantly predict endogenous variables (competition performance). (ii) The effect of exogenous variables on the mediating variable (communication skills) should be significant. (iii) The relationship between the mediator and endogenous variables should be significant. After all the criteria are met, when the mediator variable is included in the model that explains the relationship between endogenous and exogenous variables, there is expected to be a significant decrease in the amount of the relationship in the first stage, or it will lose its meaning. The disappearance of the relationship between endogenous and exogenous variables indicates that the mediating variable is strong and unique (full mediation effect). Although there is a significant decrease in the level of the relationship, the relationship still retains its meaning, indicating a partial mediation effect.

3. Results

During the analysis of the data, first of all, correlation analysis was performed in order to test the relationships between the variables in the research. Relationships between variables are presented in Table 2.

In Table 2, it was found that there was a statistically significant relationship between all the variables in the study.

After examining the relationships between the endogenous and exogenous variables of the study, a two-stage method was followed for the mediation analysis with the structural equation model (Anderson and Gerbing, 1988). In the first stage, a measurement model was created with confirmatory factor analysis, and thus, it was tested whether the relationships between latent and observed variables were acceptable or not. Then, the relationships between latent variables were tested with the structural model.

Validation measurement models are essential for testing structural equation models (Şimşek, 2020). The fit indices obtained from the measurement model are as follows: [χ^2/sd = 1.85; CFI = 0.92; GFI = 0.91; SRMR = 0.09; RMSEA = 0.06]. These show that all latent variables fit well with the indicator variables and other latent variables they represent (Tabachnick et al., 2007).

TABLE 2 Investigation of the relationship between variables by Pearson product–moment correlation.

	n	*M*	*SD*	1	2	3	4
1. Performance point	241	10.78	5.40	-			
2. Empathy	241	4.30	1.06	0.600**	-		
3. Cohesion	241	4.96	1.18	0.761**	0.716**	-	
4. Communication skills	241	3.71	0.71	0.707**	0.615**	0.702**	-

**$p < 0.01$.

After verifying the measurement model, three different models created for the research were tested, respectively. In this context, Model 1 tested the direct predictive effects of empathy and communication skills on athletes' competitive performance. Findings related to Model 1 are presented in Figure 1.

Considering the model whose fit indices [χ^2/sd = 1.81; CFI = 0.94; GFI = 0.91; RMSEA = 0.06, SRMR = 0.060] were tested in Figure 1, it can be said that all latent variables in Model 1 have a significant relationship with the observed variables they represent ($p < 0.01$). Model 1 shows that empathy and communication skills positively predict competition performance ($\beta = 0.15$, $p < 0.01$, $\beta = 0.84$, $p < 0.01$).

After confirming the hypothesis in Model 1, the second stage of mediation relations should be applied. At this stage, the mediation effect of the model is included, and the parameters related to the direct and indirect relationship processes between the predictor variables and the predicted variable are examined. In this context, the model designed in Model 1 included communication skills between empathy, team cohesion, and competition performance and was tested as Model 2. Findings for Model 2 are presented in Figure 2.

According to the model in Figure 2, χ^2/df = 1.64 was significant at the $p < 0.01$ level. It was determined that the goodness of fit indices of the structural model (RMSEA = 0.076, CFI = 0.92, GFI = 0.94, SRMR = 0.065) were at an acceptable level (Tabachnick et al., 2007; Çokluk et al., 2012). These values show that the established structural model is a good fit. Thus, the hypothesis that communication skills mediate the relationship between empathy and team cohesion and competition performances have been confirmed. According to this result, empathy, team cohesion, and communication skills explain 53% of the total competition performance. On the other hand, when Figure 2 is examined, empathy had a significant effect on competitive performance ($\beta = 0.16$ $p < 0.01$) in Model 1, but this significant relationship disappeared after the team cohesion variable was included ($\beta = 0.05$, $p > 0.05$). Similarly, in Model 1, while team cohesion had a significant effect on competition performance ($\beta = 0.84$, $p < 0.01$), its effect decreased after the communication skills variable was included in the model ($\beta = 0.41$, $p < 0.05$). With the addition of the team cohesiveness variable to the model, a significant change was observed in the correlation coefficients between the variables, which can be considered a strong indication that there may be mediation relationships. In addition, when Figure 2 is examined, it is seen that the predictive effect of communication skills on competition performance is insignificant if there are direct and indirect ways between the variables ($\beta = 0.11$, $p > 0.05$). Therefore, the full mediation role of the communication skills variable was tested by subtracting the direct paths to competitive performance from the empathy and team cohesion variables. This model, called Model 3, deals with full mediation relationships between variables. The structural model that considers the full mediation relationship is presented in Figure 3.

Model 3 indices and parameters [χ^2/df = 1.65; RMSEA = 0.055; CFI = 0.95; GFI = 0.93; SRMR = 0.052] show that the pattern under test and communication skills mediation is confirmed. When Figure 3 is examined, it is seen that empathy ($\beta = 0.52$, $p < 0.01$) and team cohesion ($\beta = 0.86$, $p < 0.01$) predict competitive performance through communication skills. Considering the model 2 parameters, it is understood that there are improvements in statistical values after the paths showing low or insignificant predictions are removed from the model. For this reason, the good fit of the hypothesized model and the observation of a significant change in the path coefficients between the variables were accepted as indicators of the mediating role of communication skills. In addition, the predictive effect of communication skills on competitive performance was determined as $\beta = 0.76$, $p < 0.01$. Compared to Model 2, it is thought that there is a significant increase in the predictive coefficient of team cohesion ($\beta = 0.11$, $p < 0.01$) on competitive performance. These values are

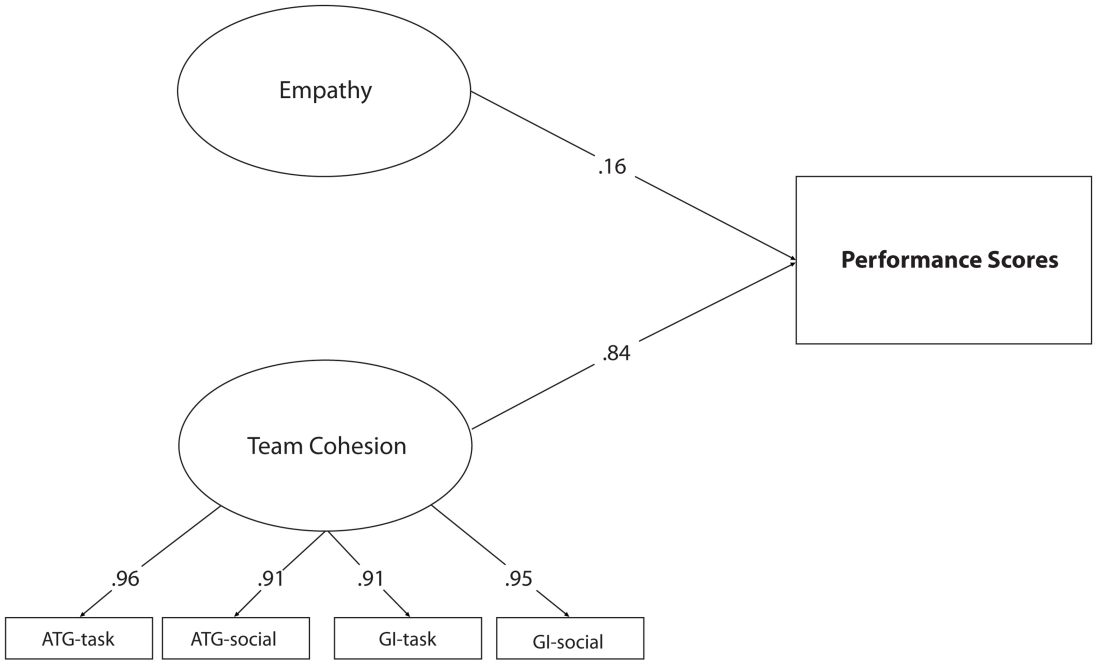

FIGURE 1
Standardized SEM results for Model 1.

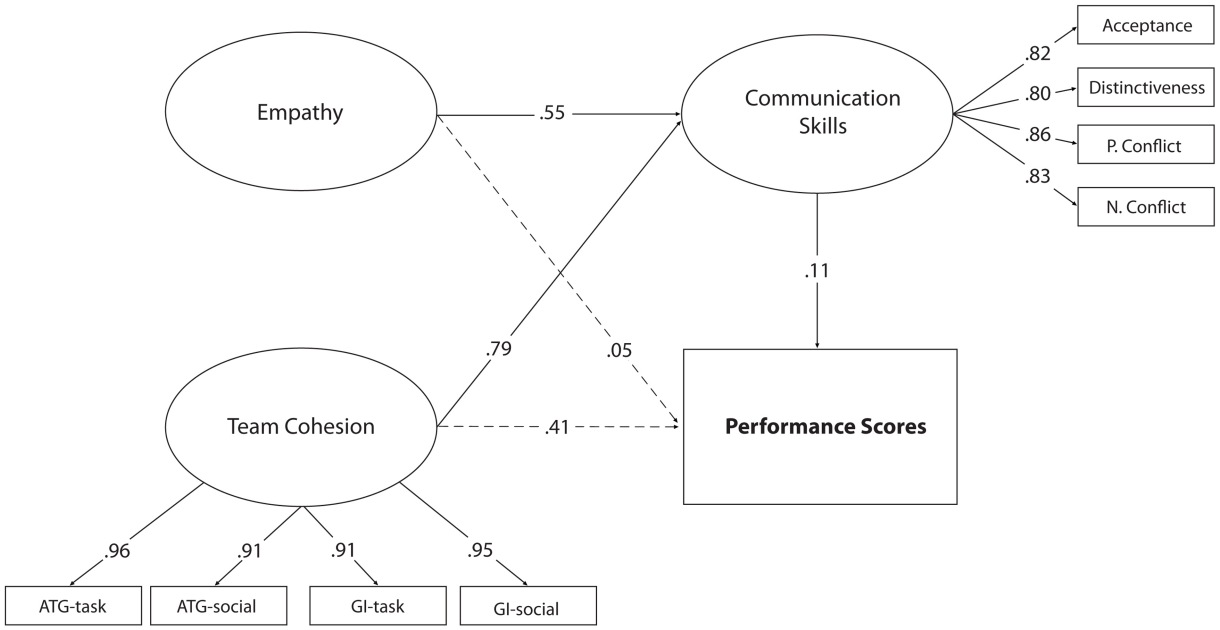

FIGURE 2
Standardized SEM results for Model 2.

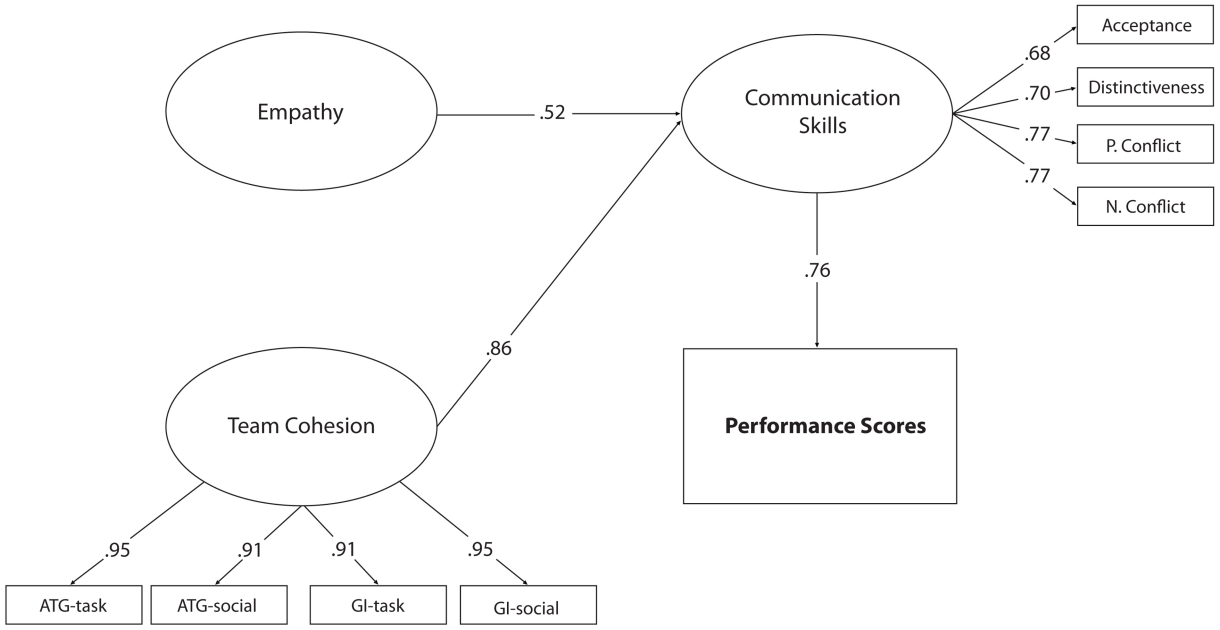

FIGURE 3
Standardized SEM results for Model 3.

obtained by removing low or insignificant relationship paths in Model 2 from the model.

4. Discussion

Increasing competition in the sports world has caused athletes to approach each other regarding physical and physiological characteristics (Ostojic et al., 2006; Sporis et al., 2009; Torres-Luque et al., 2016). The importance of psychological factors has increased in the ability of athletes with similar technical, tactical, and power parameters to be superior to each other (Weinberg and Gould, 2019). Revealing the relationship between psychological parameters that affect performance will shed light on athletes and coaches. In this context, the research aimed to determine the mediating role of communication skills in the effect of empathy and group cohesion on competition performance.

The effect of predictive variables on the competitive performance of curlers can be discussed in two ways, according to the research findings. The first category is direct effects, and the second category is indirect effects. The direct effects of empathy and group cohesion on competitive performance can be discussed. As indirect effects, the predictive effect of empathy and group cohesion on competitive performance can be discussed *via* the communication skills variable.

The results of the study showed that empathy has a positive effect on competitive performance. Neurologically, empathy is explained by the common coding principle, which assumes a bidirectional link between perception and action (Gentsch et al., 2016). This aspect of empathy allows the observer to put himself or herself in the other person's shoes with associated neural, autonomic, and somatic responses to events experienced by another person (Preston and De Waal, 2002; Biven and Panksepp, 2007; Preston et al., 2013). This approach is consistent with the principle of standard coding, which assumes a bidirectional link between perception and action in terms of shared perceptual-motor representations and shared resources in the functional architecture of the brain (Hommel et al., 2001; Decety and Meltzoff, 2011). Empathy may be an essential psychological skill for success in sports competitions, as athlete performance requires a bidirectional link between perception and action and a high level of expertise and shared resources in the brain's functional architecture (Sevdalis and Raab, 2014). For example, in team sports, athletes must replace an opponent or teammate to anticipate their reactions, understand the opponent's and teammates' emotions, imagine their reactions, and make the right decision in an instantaneously changing environment (Budnik-Przybylska et al., 2021). The athletes' morale can deteriorate in curling, especially after unsuccessful shots. In such cases, athletes with high empathic tendencies can help increase performance by preventing their teammates from psychologically dropping out of the game (Shima et al., 2021).

They can be considered aspects of a close link between perception and action, in the sense that a curler's understanding of the cognitive and emotional aspects of the target (stone, teammate, opponent) may be related to the degree to which he empathizes with that target while experiencing actions, emotions, and somatosensations (Keysers, 2011; Sevdalis and Raab, 2014). Jola et al. (2012) used transcranial magnetic stimulation (TMS) to measure corticospinal excitability *via* motor-evoked potentials (MEPs) in both hands and arms while watching participants' dance moves. The results showed that for watchers who had visual experience in a particular dance style (i.e., Indian dance), higher scores in fantasy were positively associated with more excellent MEPs in muscle-controlling arm movements. This result completes the relationship between activity in the action-observation network and aspects of empathy. Empathic tendencies may be associated with positive attitudes and emotions in interpersonal settings. In coach-athlete dyads, positive perceptions of a partner's viewpoint were associated with empathic accuracy for both coaches and athletes; ultimately, increased empathic accuracy was associated with higher levels of satisfaction with training, though only for athletes (Lorimer and Jowett, 2009).

This potential can be exploited using designs that evaluate empathy in different performance areas. For example, empathy in sports environments; (i) performance can be used to optimize empathy (by providing appropriate educational environments, experiences, and interventions) (ii) or vice versa to optimize performance (for example, by improving behaviors, interactions, and relationships to promote desired positive effects) (Sevdalis and Raab, 2014). In addition, although empathy had a relatively low predictive effect on competitive performance in Model 1, this effect increased in Model 2, where communication skills were included in the analysis. That is, empathy strongly influences competition performance through the communication skills variable.

When the communication skills variable is included in Model 2, the disappearance of the direct predictive effect of empathy on competition performance shows that communication skills have a mediating role, and type II error is prevented. Empathy is an essential force behind many positive prosocial and social behaviors that foster team cohesion and cooperation (Johnson et al., 2005; Jolliffe and Farrington, 2006; Luo and Xie, 2018). Lack of empathy can play a critical role in developing group members' exclusion and other behavioral problems in team sports (LeSure-Lester, 2000; Jolliffe and Farrington, 2006). Since the coach cannot directly interfere with the game, the athletes take various initiatives in curling. As a result, they sometimes fail and want to see their teammates support them in every situation. Because only in this way can they make a successful shot in the next attempt. In team sports such as curling, where the level of empathy and team cohesion is low, the psychological pressure on the athletes can cause them to fail (Shima et al., 2021).

The second variable that directly and indirectly affects competition performance is team cohesion. The study showed that team cohesion positively and strongly predicted competition performance in curlers in Model 1. However, there was no significant change in the prediction coefficient with the inclusion of communication skills in Model 2. The results suggest that team cohesion predicts competition performance directly and indirectly through communication skills. Therefore, the continuation of the direct effect after the inclusion of communication skills in the model indicates a partial mediation relationship. This result is in line with the research that shows that team cohesion positively affects performance (Braun et al., 2020; Grossman et al., 2022). There is evidence in the literature that highly cohesive teams show a significant relationship with performance, as interactive sports require a high level of task dependence (Mach et al., 2010; Eys and Kim, 2017; McEwan, 2020). A meta-analysis of team environments found that the relationship between cohesion and performance in sports teams was significantly more vital than in other work teams (Carron et al., 2002). Sports teams are an example of close-knit groups that must work together to succeed. Team commitment improves coordination, effort, and results (Cranmer et al., 2020).

Kim et al. (2016) investigated the relationship between communication and group cohesion. They revealed that intra-team communication has a significant relationship with group integration-task and group integration-social sub-dimensions of team cohesion. It is claimed that intra-team communication creates conditions for higher levels of emotional commitment among team members, thus increasing team cohesion (Lauring and Selmer, 2010; Smith et al., 2013). So compliant teams tend to work more effectively and perform better than less compliant teams (Barrick et al., 2007; Smith et al., 2013).

The findings show that communication skills mediate the relationship between empathy, team cohesion, and performance. Effective intra-team communication can assist the athletes of an interactive sports team by directing (i.e., planning), encouraging (i.e., motivating), and evaluating (i.e., appraising) the performance of each member (Cunningham and Eys, 2007). In team situations where conflict is likely, recognizing and resolving conflict is crucial to team success. Choi et al. (2019), who examined how effective communication skill affects the climate within the team, revealed

that although there is a positive correlation between effective communication and coach-athlete relationship and team effectiveness, there is a negative relationship with aggression. Ineffective communication can cause individuals to dislike, lose their trust, refuse to listen to each other, cause differences of opinion, and cause many more interpersonal problems within the team (Whetten and Cameron, 2016). A US-based study listed linguistic features such as coach communication, frequency of pauses, repetitions, verbs, and jargon during training for junior women's basketball teams (Masterson et al., 2006). The most important among these studies is the analysis of the relationship between the points received in the doubles tennis match and the communication established (Lausic et al., 2009). Couples' speech between play sets was coded as 'emotional' or 'action' expressions. Winning couples were found to exchange twice as many messages as losing couples, and overall communication patterns were more homogeneous than those losing couples typically exhibit. The same is true for the sport of curling. Successful team athletes in the sport of curling talk about what kind of strategy will be applied at the next end during the 1-min break between the ends and evaluate the plans to be implemented in the end. The results obtained support the model created in the research.

In sports such as curling, strategy and motivation are highly dependent on maintaining on-court communication (Alaeddinoğlu et al., 2022). Athletes who undertake the sweeping task in curling instantly inform the skip (by shouting) about where the stone will stand on the playing field after the stone is thrown. Thus, the skip gives feedback on whether the in front of the stone should be swept. Therefore, it can be concluded that the athletes of the teams that can communicate more effectively during sweeping will be more accurate. Sports events are intense and stressful environments where athletes with different goals, abilities, social structures, and communication skills come together. It is known that effective communication in the sports environment increases the athletes' effectiveness, helps them establish relationships with other athletes, and improves their motivation positively (Choi et al., 2019).

5. Theoretical contribution

It is expected that the communication skills of successful individuals in the field of art and sports will be highly effective, as is the case in occupational groups such as health, education, and management, which are in constant communication with different people. The results obtained are essential in showing that the athlete's good communication with his teammates and environment is a process reflected in the athletic performance.

Evidence has been strengthened that the relationship between communication skills and predicting what the opponent and teammates think in the competition makes the athlete more advantageous. Therefore, athletes with high empathy levels are closer to success.

Since the psychological aspects of athletic success involve very complex processes, there may be a better approach to reveal the factors affecting success because different psychological processes affect each psychological skill. Although empathy and team cohesion have a positive effect on athletic success, this effect is further increased by the intermediary role of communication skills. These results have the feature that can contribute to revealing the complex psychology-performance relationship.

On the other hand, competition performance can also be considered in terms of sport type. In individual sports, it is much easier to evaluate performance, determine the factors affecting it, follow its development, and make performance-improving suggestions compared to team sports (Özkara, 2002). For a group of athletes to be called a team, interaction, information exchange, and an emotional bond must be formed for the same purpose. It is expected that the higher the density of these elements, the higher the group dynamic will be (Aydın, 2018). The results show that for high performance in team sports, team members must have a high level of harmony, empathy, team cohesion, and communication skills.

6. Limitations and future recommendations

The most important limitation of the study is that only the teams competing in the Turkish Curling League are included in the research, and international athletes are not included in the research. In future studies, a wider group of participants can be formed by including curlers with similar expertise from different countries. In addition, only curling sport was included in the study. The results obtained by applying the model created in the research to different team sports can be compared.

In order to reveal the psychological parameters that affect the competition performance, a new and more comprehensive model can be created with different emotional intelligence elements apart from empathy and communication skills.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://doi.org/10.48623/aperta.252080.

Ethics statement

The studies involving human participants were reviewed and approved by This research was designed in accordance with the Helsinki Declaration and was approved by the Atatürk University Faculty of Sports Ethics Committee (no: 70400699-000-E.2100023787, date: 25.01.2021). The patients/participants provided their written informed consent to participate in this study.

Author contributions

DB organized the study. DB, and FA collected the data. DB, FA, FB, and SE designed the methods and wrote the first draft of the manuscript. All authors contributed to the article and approved the submitted version.

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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Preliminary revision of the *Physical Education Grit Scale* in Chinese athletes

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Objective: The work aimed to revise the *Physical Education Grit Scale* (*PE-Grit*) applicable to Chinese athletes.

Methods: Five hundred and thirty-eight professional athletes from Chinese sports colleges and provincial sports teams were selected by cluster random sampling. Then, the *PE-Grit* was analyzed for project analysis, exploratory factor analysis, confirmatory factor analysis, criterion-related validity analysis, and reliability analysis.

Results: Independent sample *t*-test and item-total correlation analysis of the questions showed that 16 items of the scale had good discrimination. According to the confirmatory factor analysis model, the factor structure consisted of 2 subscales and 4 dimensions (χ^2/df = 1.827; CFI = 0.961; TLI = 0.953; IFI = 0.961; RMSEA = 0.051). Moreover, Cronbach's α of the total scale and the 4 dimensions were between 0.751 and 0.865. A significant positive correlation existed between the *PE-Grit*, and self-control, which showed good criterion-related validity.

Conclusion: Revised *PE-Grit* can measure Chinese athletes' physical education grit for its good reliability and validity.

KEYWORDS

athletes, physical education grit, reliability, confirmatory factor analysis, revision

1. Introduction

Grit is important for deliberate practice, motivation, sports performance prediction, and achievements in sports (Fawver et al., 2020; Cormier et al., 2021; Mosewich et al., 2021). Grit, a personality characteristic positively affecting goal achievement and long-term success, reflects passion and persistence for long-term goals. Besides, independent of cognitive ability, it can encourage individuals to work hard and adhere to long-term goals (Duckworth et al., 2007; DiMenichi and Richmond, 2015). Grit includes two aspects: Consistency of interests (CI) reflects the individual's long-term grit tendency toward goals; persistence of effort (PE) refers to the individual's tendency to spend more time and energy to achieve long-term goals even when facing setbacks (Duckworth et al., 2007). Students' motivation, passion, and interest in specific academic backgrounds are related to learning content (Ryan and Deci, 2000; Ulstad et al., 2016). Athletes carry out sports activities in learning and training environments. Physical education, different from other education, is mainly reflected in the

physical components of the education process (Guelmami et al., 2022). Therefore, measuring athletes' grit should focus on the special education background and content. Grit positively affects athletes, while high-level grit is related to psychological factors such as burnout reduction (DeCouto et al., 2019), negative emotions (Doorley, 2021), optimism (Olefir, 2018), perfectionism (Martin, 2018; Fawver et al., 2020), instantaneous positive influence (Rumbold et al., 2022), specific hopes and positive emotions of sports goals (Doorley, 2021), and lower physical anxiety (Auerbach, 2018). Physical education grit can affect athletes' psychological factors, sports performance, and achievements in specific sports. Therefore, relevant research should be strengthened.

Many tools can measure grit. Grit-O and Grit-S scales developed by Duckworth et al. (2007) and Duckworth and Quinn (2009) are the most widely used and have been revised in many countries. Researchers in the context of pedagogy have developed different measurement tools, such as the *Grit Scale for Children and Adults* (Sturman and Zappala-Piemme, 2017) and *Academic Grit Scale* (Clark and Malecki, 2019). Subsequent research develops the *Grit Psychological Resources Scale* (Schimschal et al., 2022) using the nursing environment, the Triarchic Model of Grit Scale (Datu et al., 2017), and the *Multi-Dimensional Scale of Grit* (Singh and Chukkali, 2021) based on the socialist environment to evaluate grit. Guelmami et al. (2022) develop the *PE-Grit* specifically designed to measure the sports field. The *PE-Grit* is verified in the Arabic version and translated into the English version simultaneously. It consists of *Physical Grit* (*PH*) and *Academic Grit* (*AC*) and has four dimensions: physical interest (PHI), academic interest (ACI), physical effort (PHE), and academic effort (ACE). Grit has a complex structure. The *Grit Scale for Children and Adults* is a single-factor scale that cannot measure grit in sports (Sturman and Zappala-Piemme, 2017). The *Academic Grit Scale*, not including interest and physical input, cannot assess grid in physical education (Guelmami et al., 2022). Compared with the two dimensions of Grit-O and Grit-S, the *PE-Grit* is refined into physical and academic to measure athletes' grit. Therefore, Guelmami et al. (2022) conducted a reliability and validity test to verify *PE-Grit*. Cronbach's α of the four sub-dimensions is between 0.83 and 0.86, indicating the good consistency of the scale. KMO = 0.88 in the exploratory factor analysis (EFA). Confirmatory factor analysis (CFA) is used to analyze three different models. Two subscales and four-dimensional third-order factor models, namely Physical Grit (PHI and PHE) and Academic Grit (ACI and ACE), are obtained by calculating the optimal fit index with good construct validity. González-Bernal et al. (2022) verified it in Spanish middle school physical education teaching. Cronbach's α of four dimensions is 0.81, 0.83, 0.78, and 0.82, which has good construct validity.

Self-control is positively correlated with grit (Toering and Jordet, 2015; Olefir, 2018; Shields et al., 2018; Tedesqui and Young, 2018). Low grit indicates a high anxiety disorder score (Crane et al., 2020). Grit is a personality resource to overcome anxiety in sports if combined with self-efficacy, self-control, and optimism (Olefir, 2018). The *PE-Grit*, developed based on Grit-S, Grit-O, and *Academic Grit Scale*, is assumed to be positively related to Grit-S and self-control.

Currently, researchers do not deeply study grit in physical education in China. Although the adaptability of the *PE-Grit* has been verified in Arabic and Spanish, it has not been revised for Chinese athletes. The work aimed to bring the *PE-Grit scale* from the English context to the Chinese context and the athlete context of sports. Then, the *PE-Grit* for Chinese athletes was developed by verifying its reliability and validity among athletes.

2. Objects and methods

2.1. Research objects

The work was approved by the Ethics Committee of Shenyang Institute of Physical Education. Combined with online and offline data, 600 professional athletes from Chinese Sports Colleges and Universities and provincial sports teams were selected by cluster random sampling, and 538 samples were finally included. The average age of the valid questionnaires was 21.03 ± 2.56, and the average training period was 5.08 ± 2.32. The samples' participation in the highest-level competition was as follows: Three people participated at the international level, 80 at the national level, 280 at the provincial level, 154 at the municipal level, and 21 did not participate. Sports included basketball, volleyball, football, badminton, table tennis, tennis, rugby football, skiing, skating, swimming, and track and field. They were divided into two groups for exploratory and confirmatory factor analysis, respectively.

Sample 1: Two hundred and twenty-five samples were randomly selected for exploratory factor analysis, with an average age of 21.01 ± 3.08, including 154 males (68.4%) and 71 females (31.6%). Sample 2: The remaining 313 were used for confirmatory factor analysis, with an average age of 21.04 ± 2.10, including 178 males (56.9%) and 135 females (43.1%).

2.2. Research tools

2.2.1. *Physical Education Grit Scale (PE-Grit)*

Guelmami et al. (2022) developed a scale for measuring grit in physical education based on its uniqueness. The scale contains 16 topics and was divided into subscales PH and AC. Besides, it included four dimensions, PHI (e.g., I don't give many important physics training meetings), ACI (e.g., I am always interested in gaining new theoretical knowledge), PHE (e.g., intense physical exercise will never hinder me), and ACE (e.g., I do not always modify all theoretical topics). The scoring method was Likert's 7-point scoring, where 1 meant a strong disagreement, and 7 meant a strong agreement.

2.2.2. *Simple Grit Scale* (Grit-S)

The Grit-S on Chinese professional and college athletes was compiled by Duckworth and Quinn (2009) and revised by Liang et al. (2016), including two subscales of interest consistency and persistence effort, and eight items. The scoring method was Likert's 5-point scoring, from 1 (very inconsistent) to 5 (very consistent), and the four items in persistence effort were scored in reverse. Cronbach's α of the total scale was 0.843, while that of the two subscales was 0.847 and 0.814, respectively.

2.2.3. *Simple Self-Control Scale* (BSCS)

A Simple Self-Control Scale was prepared by Morean et al. (2014) and revised by Luo et al. (2021). Seven items of the scale

included two dimensions: Self-Discipline and Impulse Control. The scale adopted Likert's 5-point scoring from "completely inconsistent" to "completely consistent," and items 2, 4, 6, and 7 were reverse counting. The higher the score, the higher the level of self-control. Cronbach's α of the total scale was 0.829, while that of the two subscales was 0.789 and 0.852, respectively.

2.3. Research methods

2.3.1. Research procedures

The work has obtained authorization for scale revision from Guelmami. (1) Two English major professors and two sports psychology professors were invited to independently translate the topics of the original scale. The differences in translation were compared to obtain the modified Chinese version. (2) Two more bilingual professors in sports psychology were asked to translate the Chinese version back into English. (3) The similarities and differences between the translated English and the original text were compared. The items with large differences in translation were modified to improve the accuracy of the questionnaire translation. (4) Two sports psychology professors and five psychology graduate students were asked to evaluate the validity of the content so that it conformed to Chinese culture and semantics in terms of expression habits and life customs. For example, academic interest was described as study interest in the work; academic effort was described as an academic investment in the work. (5) Thirty Chinese athletes were randomly selected to complete the scale so that Chinese athletes could easily understand. Then the final questionnaire was formulated.

Questionnaire survey: First, athletes in the test filled out an informed consent. Then, they filled out demographic data and the questionnaire. The testing process was combined online and offline. One hundred and twelve samples were randomly selected to fill out the *PE-Grit* to investigate the reliability of the retest 1 month later.

2.3.2. Statistical methods

Data were analyzed by *SPSS25.0* and *Amos26.0*, while the discrimination was investigated by project analysis. Besides, the concordance coefficient was determined by reliability analysis, while the evidence of structural validity was obtained through confirmatory factor analysis. Meanwhile, the work selected some fitting indices: the chi-square goodness-of-fit statistic, the Tucker-Lewis Index (TLI), the comparative fit index (CFI), the incremental fit index (IFI), and root mean square error of approximation (RMSEA) to determine the model's fitting degree. Finally, correlation analysis was used to examine the correlation between different variables.

3. Results

3.1. Project analysis

Two hundred and twenty-five subjects in sample 1 were sorted according to the total scores of PH and AC scales, and the first and last 27% were taken as the high and low groups for independent sample *t*-tests. Some differences in the two subscales' items between the high and low groups ($P < 0.001$) (see Table 1). Item-total correlation referred to the correlation between the item and the total score of the corresponding subscale. The correlation coefficients of PH and AC items with the total score of the scale were between 0.527–0.735 and 0.545–0.735, respectively. Therefore, the correlation coefficients reached a significant level ($P < 0.001$).

3.2. Validity analysis

3.2.1. Exploratory factor analysis

Exploratory factor analysis of PH was performed with data in sample 1. KMO = 0.766, $\chi^2 = 618.246$, df = 28, and $P < 0.001$, which were suitable for the analysis. Then, two factors with eigenvalues of 3.057 and 2.023 were extracted by principal component analysis and lithotripsy map test, and the cumulative variance contribution

TABLE 1 Independent sample *T*-test and item-total correlation coefficient ($n = 225$).

PH			AC		
Items	*r*	*t*	Items	*r*	*T*
PHI1	0.625**	10.617***	ACI1	0.686**	14.222***
PHI2	0.690**	15.042***	ACI2	0.735**	16.100***
PHI3	0.735**	16.409***	ACI3	0.722**	13.270***
PHI4	0.702**	13.456***	ACI4	0.726**	11.113***
PHE1	0.539**	7.306***	ACE1	0.585**	7.985***
PHE2	0.527**	6.709***	ACE2	0.585**	7.100***
PHE3	0.536**	7.886***	ACE3	0.569**	7.614***
PHE4	0.545**	7.171***	ACE4	0.545**	7.066***

PH, Physical grit subscale; AC, Academic grit subscale; PHI, physical interest; PHE, physical effort; ACI, academic interest; ACE, academic effort.
**$P < 0.01$; ***$P < 0.001$.

TABLE 2 Results of exploratory factor analysis ($n = 215$).

Items	Mean	SD	Factor loading	Cronbach's α after deleting items
PHI1	4.453	1.677	0.776	0.839
PHI2	4.293	2.040	0.822	0.840
PHI3	4.507	1.653	0.776	0.834
PHI4	4.578	1.619	0.851	0.834
PHE1	5.467	1.405	0.890	0.840
PHE2	5.022	1.354	0.707	0.838
PHE3	5.244	1.398	0.720	0.837
PHE4	5.133	1.268	0.754	0.837
ACI1	4.556	1.540	0.794	0.845
ACI2	4.502	1.714	0.915	0.845
ACI3	4.396	1.398	0.785	0.849
ACI4	4.631	1.483	0.843	0.845
ACE1	5.253	1.425	0.757	0.846
ACE2	5.204	1.347	0.745	0.838
ACE3	4.867	1.395	0.766	0.840
ACE4	4.729	1.415	0.715	0.842

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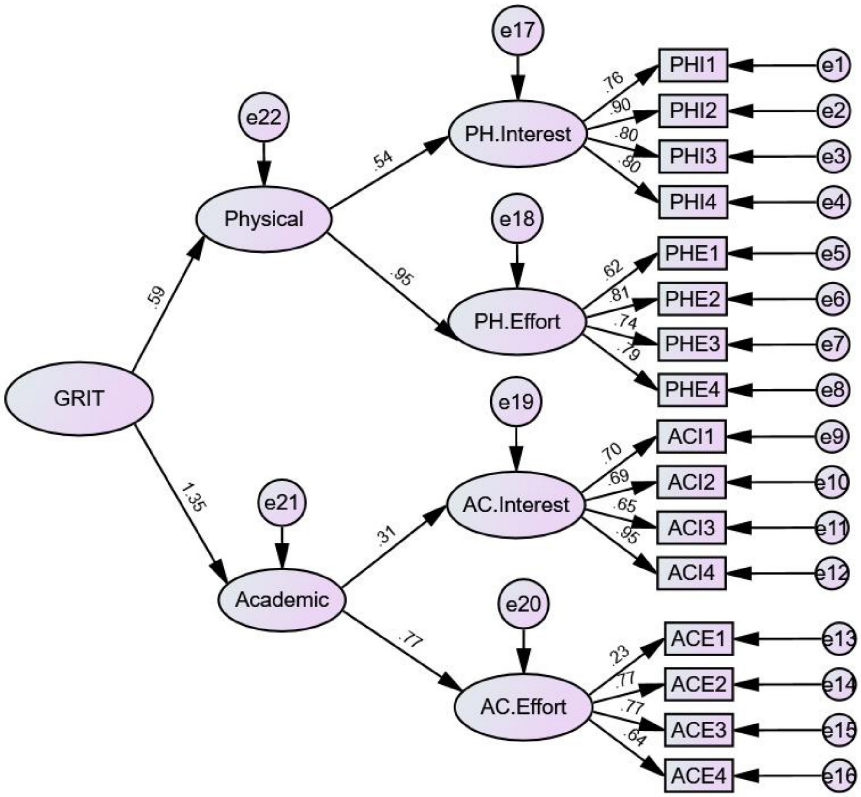

FIGURE 1
The third-order factor model of the *PE-Grit*. All parameters are standardized and significant at the 0.01 level.

rate was 63.499%. Besides, the factor load of each item after the orthogonal rotation of the maximum variance method was between 0.707 and 0.890 (see Table 2). Exploratory factor analysis of PH was carried out, and the variance weight of factors was 51.854 and 48.146%, respectively.

Similarly, data in sample 1 were used to analyze the exploratory factors of AC. KMO = 0.790, χ^2 = 682.960, df = 28, and $P < 0.001$, which were suitable for the analysis. Then, two factors with eigenvalues of 3.382 and 1.772 were extracted by principal component analysis and lithotripsy map test, and the cumulative variance contribution rate was 64.424%. Besides, the factor load of each item after the orthogonal rotation of the maximum variance method was between 0.715 and 0.915 (see Table 2). Exploratory factor analysis of AC was carried out, and the variance weight of factors was 54.984 and 45.016%, respectively.

3.2.2. Confirmatory factor analysis

Third-order factor confirmatory factor analysis of data in sample 2 shows that the model fits well (see Figure 1). Table 3 shows fit indices.

The parameters of the third-order factor model of the *PE-Grit* in Figure 1 are standardized and significant when $P = 0.01$.

TABLE 3 Fit indices of confirmatory factor analysis.

χ^2/df	TLI	CFI	IFI	RMSEA
1.827	0.953	0.961	0.961	0.051

3.2.3. Criterion-related validity

The *Grit-S* and *BSCS* were used as criterion questionnaires to test the criterion-related validity of the overall sample. The total score of the *PE-Grit* is positively correlated with that of the *Grit-S* and *BSCS* (see Table 4), indicating that physical education grit is positively correlated with self-control.

3.3. Reliability analysis

Reliability analysis showed that Cronbach's α of PH and AC subscales was 0.845 and 0.758, respectively; that of PHI, ACI, PHE, and ACE was 0.865, 0.827, 0.833, and 0.751, respectively; that of the total scale was 0.849. Cronbach's α after deleting each item was between 0.834 and 0.849, with a maximum of no more than 0.849 (see Table 2). Therefore, there was no need to delete any question items.

Cronbach's α of PH and AC subscales was 0.889 and 0.863, respectively, after retest reliability; that of PHI, ACI, PHE, and ACE was 0.903, 0.878, 0.888, and 0.858, respectively; that of the total scale was 0.920.

4. Discussion

The work revised the *PE-Grit* that was suitable for Chinese athletes. Sixteen items of the questionnaire had good item

TABLE 4 Correlation coefficients between the *PE-Grit*, *Grit-S*, and *BSCS*.

	1	2	3	4	5	6	7	8	9	10	11
1. PE-Grit	1										
2. PH.Interest	0.397**	1									
3. PH.Effort	0.738**	0.397**	1								
4. AC.Interest	0.549**	0.229**	0.105*	1							
5. AC.Effort	0.704**	0.287**	0.535**	0.198**	1						
6. Grit-S	0.311**	0.218**	0.283**	0.186**	0.161**	1					
7. CI	0.838**	0.597**	0.651**	0.449**	0.597**	0.253**	1				
8. PE	0.815**	0.624**	0.621**	0.393**	0.587**	0.236**	0.437**	1			
9. BSCS	0.301**	0.299**	0.157**	0.212**	0.134**	0.385**	0.195**	0.214**	1		
10. Self-Discipline	0.270**	0.302**	0.159**	0.172**	0.074	0.300**	0.180**	0.215**	0.766**	1	
11. Impulse Control	0.231**	0.203**	0.107*	0.176**	0.138**	0.331**	0.146**	0.147**	0.868**	0.346**	1

**$P < 0.01$.

discrimination after item analysis. Cronbach's α of PH and AC subscales was 0.845 and 0.758, respectively; Cronbach's α of PHI, ACI, PHE, and ACE was 0.865, 0.827, 0.833, and 0.751, respectively; Cronbach's α of the total scale was 0.849. Cronbach's coefficient α of *PH* and *AC* Subscales was 0.889 and 0.863 after retest reliability, respectively; Cronbach's α of PHI, ACI, PHE, and ACE was 0.903, 0.878, 0.888, and 0.858, respectively; Cronbach's α of the total scale was 0.920, which reached the psychometric properties.

Confirmatory factor analysis showed that the internal structure and items' number of the revised questionnaire were the same as those of the original. The standardized load coefficients of the items on the corresponding subscales were greater than 0.40, with χ^2/df less than 3, CFI and TFI greater than 0.90, and RMSEA and SRMR less than 0.08. Fit indices met the psychometrics standard, indicating that the scale had a clear structure.

The work adopted the *Grit-S* and *BSCS* as questionnaires to test the correlation validity of the *PE-Grit* criteria, and PHI, ACI, PHE, and ACE *w*ere positively correlated with grit in the *PE-Grit*. Grit is passion and persistence for long-term goals (Duckworth et al., 2007), while grit in sports can promote professional skills' development by prolonging the time to participate in and adhere to practical activities (Hodges et al., 2017). Physical education grit is the personality embodiment of grit in sports, so they are similar but with differences.

Besides, the work proved that the *PE-Grit* was positively correlated with self-control. Self-control refers to the willpower to suppress impulsive and short-term behavior, while grit refers to the years of effort required to achieve a life goal (Duckworth and Gross, 2014). Self-control is positively correlated with grit (Toering and Jordet, 2015; Olefir, 2018; Shields et al., 2018; Tedesqui and Young, 2018), that is, it is positively correlated with physical education grit. Therefore, the revised athletes' *PE-Grit* has good reliability and validity and can evaluate Chinese athletes' physical education grit.

5. Limitations and future research directions

The work has some limitations: (1) *PE-Grit* was only tested among Chinese athletes, without considering age groups, so subsequent research should supplement this verification. (2) Gender and sports training background are not controlled, so subsequent research can explore the differences in physical education grit by gender. (3) Since the questionnaire background is a Western culture, subsequent research can develop a scale with Chinese characteristics to measure grit in sports.

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 Shenyang Institute of Physical Education. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

RZ reviewed the literature and wrote the manuscript. RZ and SG collected and analyzed data. RZ and GD outlined the structure of the manuscript, reviewed the literature, and wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Supplementary material

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The effect of physical exercise on the anxiety of college students in the post-pandemic era: The mediating role of social support and proactive personality

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In order to study the current situation of the anxiety of college students in the post-pandemic era and the effect of physical exercise on anxiety, this study explores the influence of social support and proactive personality as mediating variables on the anxiety of college students from the perspective of physical exercise. Firstly, anxiety symptoms and anxious emotions are defined. Secondly, a questionnaire survey is conducted for a well-known university in a certain city, and different questionnaire scales are developed from the physical exercise, anxiety, social support, and proactive personality assessment of college students. Finally, the results of the survey are statistically analyzed to explore the relieving effect of physical exercise on anxiety. The results reveal that there is a significant gender difference in the level of physical exercise, and the amount of physical exercise of the male students is generally higher than that of female students. In addition, the intensity, time, and frequency of exercise of male students are more than that of female students, but there is no obvious difference between them and whether they were only children. Physical exercise habits, social support, proactive personality traits, and anxiety of college students have a significant correlation. Through the analysis of the chain mediation effect, Ind2 (0.0140) is the largest coefficient among the three paths, indicating that the path of influencing social support through physical exercise habits, followed by affecting proactive personality traits, and then impacting anxiety has the strongest explanatory force. According to the results, strategies to relieve the anxiety of college students are given. This study can provide a reference for the research on the methods to alleviate their anxiety under the influence of the epidemic.

KEYWORDS

post-pandemic era, physical exercise, anxiety of college students, social support, proactive personality

1. Introduction

Post-pandemic era is a state of people's production and life after the outbreak of the Corona Virus Disease 2019 (COVID-19) (Petersen et al., 2019; Tang et al., 2022; Zheng et al., 2022). In the early days of a post-pandemic era, when the number of infections increases rapidly, there may be some confusion and panic in the short term. However, as people gradually adapt to and accept the situation, they will reach a new steady state and find a new balance between epidemic

prevention and economic development (Siying et al., 2021; Mo and Ming, 2022; Yang et al., 2022). Because of the epidemic, many people's lives have changed, and it has triggered a lot of new thinking, such as the advantages and disadvantages of online and offline, the severe damage caused to various industries during the epidemic, the length of the recovery period, and so on, will change many people's lives (Huang et al., 2021). College students are no exception, with delayed start times and online teaching becoming routine. Many foreign students cannot study abroad normally due to the epidemic (Rogowska et al., 2020). Learning efficiency has plummeted, and there is no way to go to the library, laboratory, and off-campus internship. Normal campus life has been greatly changed. For college students who are studying or about to enter social work, the initial feeling of freshness has gradually changed to a psychological state of anxiety and depression (Bamber and Morpeth, 2019; Wang et al., 2020; Watt et al., 2020). However, since the environment has been such, the best way to cope is to seek self-regulation and rely on the support of the surrounding society to achieve their academic goals.

With epidemic prevention and control normalized, college students' extracurricular activities have been significantly reduced, and all off-campus activities have been canceled. Nucleic acid testing and vaccination have also become "frequenter" in the daily life of college students, which makes people understand the importance of physical health. Anxiety is produced by the accumulation of adrenaline, but a certain intensity of aerobic exercise can consume the adrenaline of the human body, thus achieving the purpose of relieving anxiety (Huang et al., 2018; Dominski and Brandt, 2020; Lee et al., 2021). Regular exercise can not only help people keep fit and increase vitality, but also improve their appearance and build up self-confidence (Zeng et al., 2018; Saeed et al., 2019; Grasdalsmoen et al., 2020). What is more, during the process of exercising, exercise also helps to release the tension of anxiety, so that both the body and mind are greatly relaxed. As such, moderate physical exercise has a positive effect on relieving the anxiety of college students (Goel et al., 2018; Ren and Li, 2020; Watt et al., 2022).

Moreover, after college students have anxiety, depression, and other unhealthy psychological states, often accompanied by a large number of negative emotions accumulation, in addition to physical exercise, their self-adjustment ability and social support from the surrounding environment also have a positive effect on easing anxiety (Rith-Najarian et al., 2019; Chang et al., 2021; Ren et al., 2021). That is, the mediating role of external the environment in relieving anxiety is considered. Thereupon, it is of practical significance to study the influence of physical exercise on the anxiety of college students in the post-pandemic era.

Although there have been many similar research conclusions, there are still some limitations. For example, they do not take into account the specific mediating effect of college students' social support and personality traits on the research topic under specific circumstances, such as the COVID-19 pandemic. Thus, the questionnaire survey and comparative study are adopted. Firstly, this study reveals the impact of the post-epidemic era on various industries and the living situation of college students. It is hypothesized that there is a correlation among college students' physical exercise habits, anxiety, and mediating variables (social support and proactive personality). Secondly, different questionnaire scales are developed according for college students to explore the easing effect of physical exercise on anxiety. Besides, the results of the survey are analyzed statistically. Finally, according to the results, strategies and suggestions to relieve the anxiety of college students are put forward. This study can alleviate the anxiety of college students and help them maintain healthy psychological conditions.

2. Literature review

This epidemic can be said to have had the largest and most serious impact in all mainstream countries since the beginning of the new century. In the foreseeable post-pandemic era, the post-western world is bound to undergo a larger-scale ideological transformation. "Post-pandemic era" can also be understood as the era after the epidemic, which affects people's consumption habits, economy, culture, education, and others (Lin, 2022; Yan et al., 2022; Zhang, 2022). This has a great impact on college students, and even many students even suffer from an anxiety disorder, which is a serious mental illness. As anxiety causes changes in body function, it is generally accompanied by transformations in physiological and sports indicators. Many scholars give their own answers to this research.

For example, Johnston et al. (2021) conducted a 12-week quasi-experimental study aimed at evaluating the effectiveness of team sports in relieving depression, anxiety, perceived pressure, and poor sleep quality among college students. Data were collected by questionnaires before and after the test. The results suggested that team sports may help reduce depression and poor sleep quality among college students. However, physical exercise alone may not help improve anxiety and perceived stress. Siyal et al. (2021) studied how inclusive leaders can cultivate employees' innovative behaviors and creativity by drawing on the social communication theory. Glavin et al. (2022) investigated the relationship between exercise, sleep, and mood of male and female college students. Students ($N = 866$, 19.6 ± 1.4 years old, 38.7% female) were recruited from campus recreation facilities to complete demographic, Pittsburgh Sleep Quality Index (PSQI), mood (Patient-Reported Result Measurement Information System), and exercise questionnaires. The results found that women went to bed earlier, slept less efficiently, and had higher levels of anxiety and depression than men ($p < 0.05$). Lv and Kumar (2020) pointed out that connecting infrastructure closely related to people through the network plays an important role in the wide use of the network. Deng et al. (2020) conducted a web-based survey through snowball sampling to collect demographic data, mental health status, sports-related lifestyle, and problems related to online sports of university students in Wuhan City. The results denoted that mental state was remarkably correlated with regular exercise and sufficient exercise time. Ghrouz et al. (2019) explored a cross-sectional among Indian college students in which all participants completed three questionnaires: the Hospital Anxiety and Depression Inventory, the International Physical Activity Questionnaire-Brief Form, and the PSQI. The study found that there was a prominent correlation between physical activity level, sleep quality, and mental health.

In addition, the amount of exercise also has a great impact on the physiological level. For example, St Clair Gibson et al. (2018) pointed out that both central (brain) and peripheral (physiological system of the body) control mechanisms, or a combination of these mechanisms, have been supported in the field of exercise science. Therefore, both psychological and physiological driving forces are based on the steady-state principle, and their relative activities are regulated by dynamic

negative feedback activities as the basic general operating controller. Silva et al. (2021) studied the physiological and perceptual responses to aerobic exercise with and without blood flow restriction and high-intensity intermittent exercise, demonstrating the potential benefits of aerobic exercise and blood flow restriction on physical and mental health. Azizi et al. (2021) examined that training under normoxia and hypoxia conditions can be an effective factor in improving complications in overweight men through its beneficial effects on iridin levels and insulin resistance. The results demonstrated that exercise was very helpful to improve the physiological state of the human body. Jones et al. (2018) proposed that academic pressure is the biggest variable of college students' anxiety, followed by economic pressure, family support, and peer support. The influence of social demographic variables is very small, indicating that different types of students generally have anxiety, which has a large impact on the normal life of students and must be taken seriously.

In summary, existing studies have shown that different kinds and degrees of physical exercise have significant effects on the relief of poor sleep quality, anxiety, depression, and other emotions. However, the influence of the surrounding environment on the psychological state of college students is not taken into account. Most studies on the psychological state of college students under normal circumstances are less in the context of the epidemic. Consequently, the relationship between physical exercise and the anxiety of college students under a specific research background is studied, which can provide a new research idea for alleviating their anxiety.

3. Investigation of the current situation of the anxiety and physical exercise of college students in the post-pandemic era

3.1. The definition of anxiety

The word anxiety initially means that when an individual is faced with something indecisive, he or she cannot make a decision quickly, showing the inner feeling (Knowles and Olatunji, 2020). Anxiety is an emotional problem, including worry, tension, fear, and many other uncomfortable emotional feelings. It is an instinctive emotion, and everyone will have anxiety. Anxiety occurs when people are in a stressful mental state or are stimulated (Patterson et al., 2021). In fact, not all anxiety is bad. Proper stress and anxiety can motivate people to think and solve problems positively.

The scientific name of anxiety disorder is anxiety neurosis (John Lothes et al., 2021). Its main symptom is anxiety, which is a neurosis with anxiety as the main clinical manifestation. It is often accompanied by motor discomfort and physical discomforts, such as insomnia, increased heart rate, excessive sweating, loss of appetite, frequent urination, and urgent symptoms (Sprung and Rogers, 2021). Anxiety disorder is a general term that can be subdivided into the following diverse types of anxiety: general anxiety, social panic disorder, simplex phobia, panic disorder, agoraphobia, obsessive–compulsive disorder, hypochondria, etc. Different anxiety disorders show various behaviors, so the treatment is not the same, but basically will have an impact on our lives, and even affect people's normal social functions, such as being unable to study, work, do housework or even the simplest of tasks cannot be done on their own.

Severe anxiety symptoms often involve motor restlessness, such as restlessness. There will also be rubbing hands and feet, both upper and lower limbs shaking (tremor), and then serious symptoms such as wandering, and pacing back and forth. Anxiety symptoms are also often accompanied by sleep problems, mainly manifested in difficulty falling asleep. Besides, people also show inattention, focus only on their own discomfort symptoms, do not care about others, and may even be overly demanding of others to care for them. Anxiety is a normal state of mind for almost everyone when faced with difficulties or dangers. It can be said that anxiety is a positive stress instinct, and appropriate anxiety can help people summon up the courage to solve an impending crisis. However, anxiety symptoms occur when the level and duration of anxiety exceed a certain range, which can have the opposite effect, such as preventing people from dealing with the crisis before them and even interfering with normal life.

3.2. Questionnaire survey respondents and method

This study takes freshmen to seniors of a well-known university in a city as the research respondents to investigate their physical exercise, mental health (such as anxiety), social support, and personality assessment of college students in the post-pandemic era. Additionally, the mediating effects of different social support and proactive personality of college students on anxiety are analyzed. Consent is obtained from the school, teachers, and students themselves before the investigation, and students are asked to sign informed consent and privacy protection agreement to ensure that the investigation is conducted without controversy.

Based on previous studies, the following hypothesis is proposed:

> *Hypothesis 1:* There is a correlation among college students' physical exercise habits, anxiety, and mediating variables (social support and proactive personality).
>
> *Hypothesis 2:* The social support and proactive personality of college students have a chain mediating effect on the influence of physical exercise habits on anxiety. The hypothesis model is displayed in Figure 1.

The questionnaire is divided into four parts. Part 1 is the survey of college students' physical exercise habits under the influence of the epidemic. The Physical Activity Rating Scale-3 (PARS-3) was adopted, which was compiled by Japanese scholar Masao Hashimoto in 1990 and revised by Chinese scholar Deqing Liang in 1994. The PARS-3 measures the physical activity level of individuals from three dimensions: the frequency, intensity, and time of exercise. Among them, the frequency and intensity of exercise are scored by 1–5 points from levels 1–5, and the time of exercise is scored by 0–4 points from levels 1–4. The physical activity level of the respondents is calculated according to the equation of the amount of physical activity = exercise intensity × (exercise time − 1) × exercise frequency. The highest score for exercise is 100, and the lowest score is 0. Evaluation range of physical exercise amount: a small amount of exercise $\leq$19 points; Moderate exercise: 20–42 points; Large exercise $\geq$43 points. The higher the score, the stronger the level of physical activity, and the greater the amount of physical activity of the individual. After the

reliability analysis of the scale in this study, Cronbach's alpha coefficient is 0.758 > 0.7, indicating that the scale is highly reliable and suitable for investigation.

Part 2 explores the anxiety of college students, which is carried out by Generalized Anxiety Disorder (GAD-7) (Spitzer et al., 2006). The GAD-7 was compiled by Spitzer et al., consists of 7 items, and uses the 4-point scoring method, with 0 to 3 points, respectively. The total score of the GAD-7 ranges from 0 to 21. A score of 0 to 4 refers to no symptoms of anxiety, 5 to 9, 10 to 14, and 15 to 21 indicate mild, moderate, and severe anxiety symptoms.

Part 3 studies the social support situation of the students in the university, which is performed by the Social Support Rating Scale (SSRS). The scale was compiled by Xiao Shuiyuan et al., consisting of 10 items in 3 dimensions (subjective support, objective support, and support utilization). 1–5 and 8–10 items were scored with 4 points and assigned 1–4 points, respectively. 6–7 items are scored with 2 points, and they are assigned 0–1 points, respectively. The total score of the scale ranges from 12 to 66, with scores from 0 to 22, 23 to 44, and 45 to 66 indicating low, moderate, and high levels of social support, respectively.

Part 4 investigates the personality characteristics of college students. This part adopts the proactive personality scale developed by Seibert et al. (1999). This scale was mainly revised by referring to the scale proposed by Thomas et al. (1993). The original 17 items were reduced to 10 items. The reliability coefficient of this scale is 0.89, which has good measurement reliability and adopts Likert's five-point scoring method. One refers to completely inconsistent, and so on, and 5 stands for very consistent. The higher the score, the higher the level of proactive personality.

After the questionnaire design was completed, a formal questionnaire survey was conducted. A total of 600 questionnaires were distributed in the school. According to the filling situation of the questionnaire, such as whether to complete all the items and whether to fill in in a distinguishable way, 23 questionnaires that did not meet the requirements were screened out. Five hundred seventy-seven questionnaires were collected on-site, with a recovery rate of 96.17%. Then, SPSS24.0 was used for data test analysis, including independent sample T-test of gender and whether the only child, correlation analysis of physical exercise and anxiety, regression analysis, etc. Next, statistical analysis of the result data and the mediating effects of social support and proactive personality were carried out.

To further study the internal relationship between college students' physical exercise habits, anxiety, and chain mediating variables (social support and proactive personality traits), the mediating test procedure is adopted here. At present, the product of coefficients is tested directly by the Bootstrap method, which is a method of repeated sampling from samples. In this study, the model of Process v3.4 plug-in in SPSS (Figure 1) will be employed to conduct a regression test of chain mediating variables in physical exercise habits and anxiety.

4. Results and discussion

4.1. Descriptive statistical results of the questionnaire survey

The statistical results of gender, grade, and whether the only child of the students participating in the questionnaire is exhibited in Figures 2–4.

In Figure 2, there are many female students among the respondents, accounting for 68.98%, and the proportion of male students is 31.02%. Figure 3 shows that there are 267 freshmen, 213 sophomores, 74 juniors, and 23 senior students in the survey, accounting for 46.27, 36.92, 12.82, and 3.99%, respectively. Figure 4 demonstrates that the number of only children and non-only children is 315 and 262, accounting for 54.59 and 45.41%. It can be found that there are more female respondents, and most of them are freshmen and sophomores. The number of only children is slightly more than that of non-only children. This is related to the ratio of males to females in this school. Besides, the juniors and seniors are under great pressure from schoolwork and have more internships and less free time, so the questionnaire ratio is affected.

For the score of physical exercise, a score below 19 as mentioned above means a small amount of exercise; A score between 20 and 42 indicates moderate physical activity; A score greater than 43 indicates heavy exercise. The higher the score, the stronger the level of physical activity, and the greater the amount of physical activity of the individual. The statistical results are demonstrated in Figure 5.

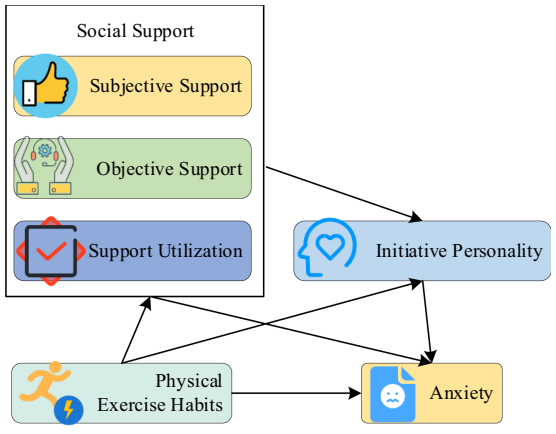

FIGURE 1
Chain mediating hypothesis model.

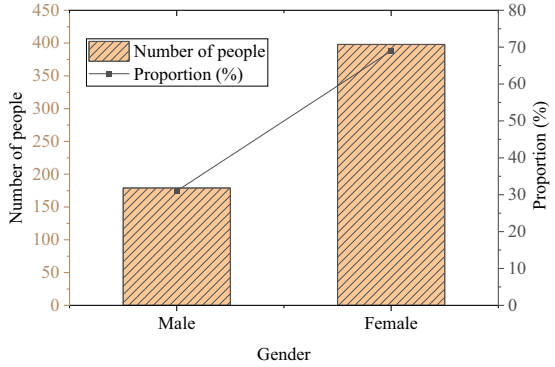

FIGURE 2
Gender distribution (*N*=577).

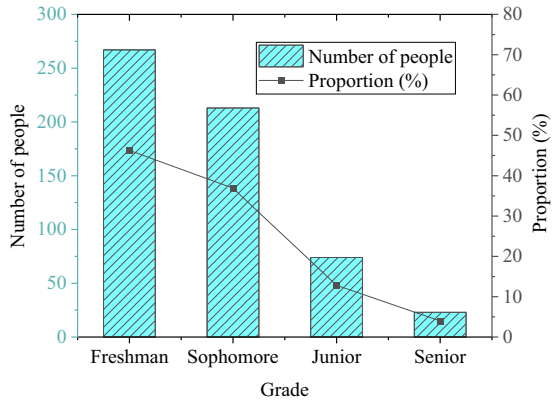

FIGURE 3
Grade distribution (*N*=577).

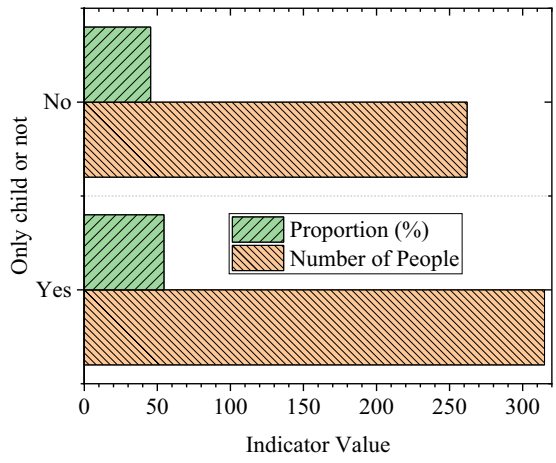

FIGURE 4
Situation of only child (*N*=577).

In Figure 5, the number of college students who score 19 points or below is 318, accounting for 55.11%, more than half of the total number. The number of students who score 20–42, and 43 or above points is 115 and 144, accounting for 19.93 and 24.96%. It can be found that more than half of college students in the post-pandemic era have a small amount of exercise, and less than one-fifth of those who maintain high exercise. On the one hand, it is restricted by the activity site during the epidemic; on the other hand, the epidemic prevention and control requirements do not allow a large number of people to gather, so the places and times of college students' activities are also limited.

Regarding the scores of anxiety of college students during the epidemic period, the scores ranged from 0 to 4, 5 to 9, 10 to 14, and 15 to 21 standing for no symptoms, mild, moderate, and severe anxiety symptoms. The details are plotted in Figure 6.

Figure 6 signifies that the anxiety score of college students ranges from 0 to 4, that is, 57.71% have no anxiety symptoms. The ratio of students with mild, moderate, and severe anxiety symptoms on a score of 5–9, 10–14, and 15–21 is 28.42, 9.19, and 4.68%. It can be seen that college students have different levels of anxiety in the era of the epidemic, and the proportion is nearly half. Thus, it needs to be highly valued, which will inevitably affect the physical and mental health, life, and study of college students.

The social support received by college students is presented in Figure 7.

Figure 7 expresses that the total score of support covers three dimensions: subjective support, objective support, and support utilization. The scores ranging from 0 to 22, 23 to 44, and 45 to 66 indicate that the level of social support is low, medium, and high, accounting for 2.08, 92.03, and 5.89%, respectively. It means that the level of social support received by most college students is at the medium level.

4.2. Data analysis

SPSS24.0 is employed to test the difference in college students' physical exercise levels and the results are outlined in Table 1.

Table 1 denotes that the average value of the low-exercise group is 8.03, which is significantly lower than the overall average value of 27.41, with a difference of about 20 points. The average value of a large amount of exercise group is nearly 40 points higher than the general level, the degree of freedom is 2, the F value is 1489.26, and sig < 0.01, illustrating that there are significant differences between diverse levels of exercise to classify physical exercise habits. Beyond that, the results of exercise with different exercise habits are also markedly different.

The independent sample T-test results of different physical exercise levels in gender and whether they are only children are signified in Table 2.

In Table 2, there is an obvious difference in the level of physical exercise between the gender, Sig < 0.01, and the amount of physical exercise of the male is generally higher than that of females, exercise intensity, time, and frequency of males are more than that of females. However, there is no significant difference between them and whether they are only children (Sig > 0.01). This is because what men usually play in society is a kind of physical beauty with a strong physique, so male students will choose to change their external image and enhance their personal charm by participating in sports, and college students are no exception. It illustrates that the physical exercise habits of college students are related to gender, and there are differences between boys and girls. However, there is no obvious relationship with whether it is an only child, indicating that the family organizational structure does not have much influence on the physical exercise situation itself.

Table 3 presents the difference in the anxiety degree of college students under different levels of physical exercise habits.

In Table 3, there is a prominent difference in the anxiety level between the group with a small and a large amount of physical exercise (Sig < 0.01); there is a remarkable difference in the anxiety level between moderate and large exercise groups, while there is no significant difference between small and moderate exercise groups. This indicates that only a high amount of physical exercise habit can significantly affect the level of anxiety. Because anxiety is not a short-term state of anxiety, but a long-term existence in the personality structure of individuals, so a short period of physical exercise cannot have a significant impact on the improvement of anxiety.

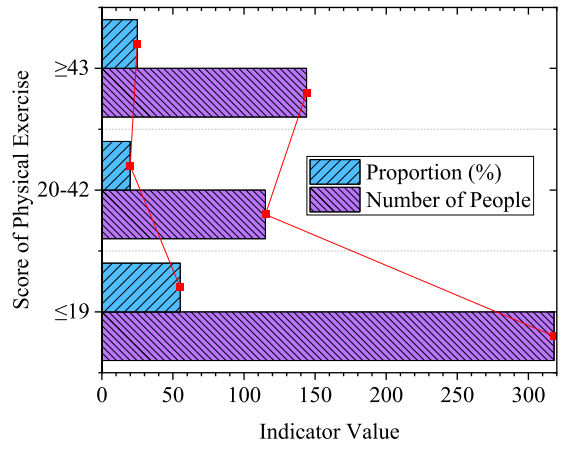

FIGURE 5
Physical exercise of college students (*N*=577).

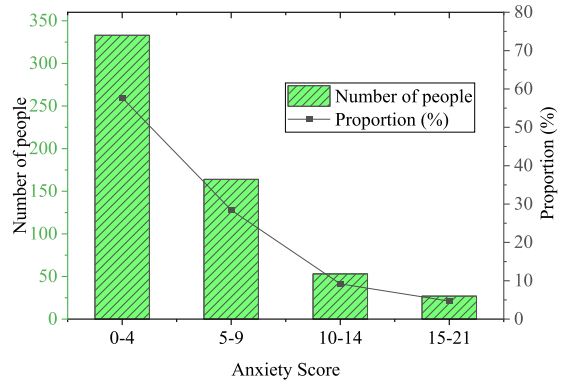

FIGURE 6
Anxiety scores of college students (*N*=577).

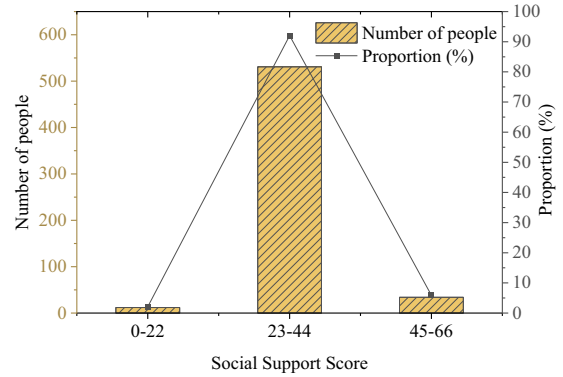

FIGURE 7
Social support scores of college students (*N*=577).

The correlation test among the four variables of physical exercise habit, anxiety, social support, and proactive personality is portrayed in Table 4.

In Table 4, there is an obvious correlation between college students' social support and physical exercise habits, and the Pearson coefficient is 0.225. It refers that these two are positively correlated, the higher the level of social support, the better the physical exercise habit; the worse the level of social support, the worse the physical activity habits. There is an evident correlation between physical exercise habits and proactive personality, and the Pearson coefficient is 0.625. It means that they are positively correlated, the higher the degree of the proactive personality trait, the better the physical exercise habit; The worse the degree of the former, the worse the latter. There is a distinct correlation between physical exercise habits and anxiety of college students, and the Pearson coefficient is −0.539. The results illustrate that physical exercise is negatively correlated with the anxiety of college students. The better the physical exercise habit, the lower the anxiety level of college students. The worse the former, the higher the latter. This is consistent with the previously proposed hypothesis 1.

TABLE 1 Division of physical exercise of college students.

Classification	*M*	df	*F*	Sig
A small amount of physical exercise	8.03	2	1489.26	0.000
Moderate exercise	29.03			
A large amount of exercise	68.90			
Total	27.41			

M represents the average value, the same as below.

Physical exercise is taken as the independent variable and anxiety is the dependent variable for regression analysis to predict the relationship between the two. The results are revealed in Table 5.

Table 5 shows that sig < 0.01 and *F*-value is 58.96, indicating that the above model passes the significance test and the linear regression model is established. Physical activity can explain 9.9% of anxiety. Then the independent variable X: physical exercise habits; the dependent variable Y: anxiety; mediating variable M1: social support; the mediation variable M2: proactive personality traits are applied to the Bootstrap method of process plug-in to test whether the model is valid. The results are expressed in Table 6.

Table 6 implies that in the regression analysis of the effect of physical exercise habits on social support, *R*-value is 0.6635, the R^2 value is 0.4536, $p < 0.01$, with statistical significance. The *R*-value of the regression analysis of physical exercise habits on proactive personality is 0.5526, and the R^2 value is 0.3098, $p < 0.01$, which is statistically significant. Social support and proactive personality traits have a significant negative effect on anxiety, the higher the social support, the lower the anxiety; the higher the degree of proactive personality, the lower the level of anxiety. These results suggest that proactive personality traits and social support have mediating effects on anxiety. The mediation pathway test is then performed, as illustrated in Table 7.

In Table 7, Ind1 means X → M1 → Y, Ind2 refers to X → M1 → M2 → Y, Ind3 stands for X → M2 → Y. The interval of the overall mediation effect is not 0, showing that the overall mediation effect is valid. There are three paths in the model. Ind1: physical exercise habits → social support → anxiety; Ind2: physical exercise → social support → proactive personality traits → anxiety; Ind3: physical exercise habits → proactive personality traits → anxiety. The coefficient of Ind2 is 0.0140, which is the largest among the three

TABLE 2 Test results of differences in physical exercise of college students on gender and whether they are only children (*N*=577).

	$\bar{X}$	*SD*	*T*	Sig
Male student	3.4258	1.069	3.265	0.000
Female students	3.1259	1.245		
Only children	3.3251	1.169	−1.425	0.859
Non-only children	3.3521	1.172		

SD stands for standard deviation, the same as below.

TABLE 3 Test results of anxiety level difference under different conditions of physical exercise.

		Difference of average value	Standard error	Sig
A small amount of physical exercise	Moderate exercise	−0.410	0.974	0.000
	A large amount of exercise	10.891*	1.096	0.000
Moderate exercise	A large amount of exercise	11.263*	0.974	0.000

* indicates significant difference.

paths, illustrating that the path of impacting social support through physical exercise habits, then affecting proactive personality traits, and then influencing anxiety is the strongest explanation. Furthermore, proactive personality and social support can also act as separate mediating variables to affect levels of anxiety, and when both levels are high, the mediating effect on anxiety level is the most obvious, which verifies hypothesis 2.

4.3. Discussion

On account of the above research results, all the hypotheses established above have been verified. The different situations of college students' physical exercise will indeed have some help to the environment of anxiety. This is similar to the findings of Frederiksen et al. (2021), who suggested that physical exercise was promoted as a means to enhance the impact of cognitive behavior therapy (CBT) on anxiety disorders. Physical exercise seems to reduce anxiety through mechanisms other than CBT, some of which may also enhance the effects of psychotherapy. Evidence from a systematic review of randomized controlled trials by Kandola et al. (2018) suggested that exercise training can reduce symptoms of anxiety and stress-related disorders such as post-traumatic stress disorder, agoraphobia, and panic disorder. Herzog et al. (2022) examined the effect of a single acute exercise session on state anxiety in subclinical samples of moderate to high anxiety

TABLE 4 Correlation test results of physical exercise habits, anxiety, social support, and proactive personality.

	Physical exercise habits	Social support	Proactive personality	Anxiety
Physical exercise habits	1			
Social support	0.225**	1		
Proactive personality	0.625**	0.596**	1	
Anxiety	−0.539**	−0.269**	−0.569**	1

** refers to an obvious difference at the 0.01 level.

TABLE 5 ANOVA test of physical exercise habits on anxiety.

	Sum of squares	Degree of freedom	Mean square	*F*	Sig	R^2
Regression	29659.36	1	29659.36	58.96	0.000	0.099
Residual	295686.55	559	519.36			

ANOVA stands for analysis of variance. a. Dependent variable: physical exercise habits; b. Predictive variable: (constant), anxiety.

sensitivity, exploring potential mediating factors including self-efficacy, self-esteem, mindfulness, subjective vitality, rumination, and emotional competence. They found that one acute exercise may not be sufficient to reduce state anxiety in subclinical individuals with moderate to high anxiety sensitivity. However, positive influence and subjective vitality may be two mechanisms that explain the beneficial effects of exercise on anxiety.

Furthermore, Naghavi et al. (2018) aimed to investigate the effects of cognitive and physical training on anxiety in older adults. Sut Txi et al. (2022) investigated the prevalence of emotional distress in athletes during Covid-19 in Malaysia. There were no significant differences between levels of stress, anxiety, and depression based on age, gender, and exercise category (individual *VS* team sports). More female athletes reported severe depression (4.19%) than male athletes (3.13%). This finding recommends further assessment, monitoring, and treatment plans for athletes, especially female athletes, to ensure their mental health and emotional well-being during the Covid-19 pandemic. It can be seen that this study has certain reliability and research basis.

5. Strategies for relieving anxiety of college students in the post-pandemic era

Based on the above results, it is necessary to establish a subjective awareness of physical exercise for the groups troubled by anxiety and depression, and regular exercise is very important. Moreover, physical exercise can enable individuals to effectively manage their own pressure and ability to bear it and has a relatively obvious effect on relieving individual anxiety, depression, and other negative emotions.

TABLE 6 Regression analysis of physical exercise habits, anxiety, social support, and proactive personality.

Dependent variable	Independent variable	Partial regression coefficient			*R*	R^2	*p*
		Coeff	*SE*	*t*			
Social support		32.5692	2.3659	15.9215	0.6635	0.4536	0.0000
	Physical exercise habits	0.5369	0.0254	21.6351			
Proactive personality		63.3695	1.5692	41.2596	0.5526	0.3098	0.0000
	Social support	0.3023	0.0025	11.2631			
	Physical exercise habits	0.3695	0.0269	0.1598			
Anxiety		12.6584	0.5236	25.6321	0.6459	0.4563	0.0000
	Social support	−0.0245	0.0059	−4.5961			
	Proactive personality	−0.0365	0.0069	−16.3256			
	Physical exercise habits	−0.5399	0.0036	−0.9962			

TABLE 7 The mediation pathway test.

Indirect effect(s) of *X* on *Y*				
Effect	Boot	SE	BootLLCI	BootULCI
Total:	0.0265	0.0036	0.0218	0.0335
Ind1:	0.0125	0.0028	0.0059	0.0154
Ind2:	0.0140	0.0018	0.0123	0.0159
Ind3:	0.0001	0.0024	0.0049	0.0059

Hence, for college students who have anxiety, irregular physical exercise is a better way to relieve it. Specific measures are as follows:

1) Moderate-intensity physical exercise

As can be seen from the above research results, only a high amount of physical exercise habit can significantly affect the level of anxiety. Thereupon, high-intensity physical exercise (overall score of physical exercise is above 43 points), such as aerobics, can improve anxiety and reduce the impact of bad emotions on life and study. For students with high scores of anxiety, moderate-intensity aerobic exercise can be adopted to reduce anxiety; for students who want to reduce anxiety for a short time, high-intensity exercise can be used to quickly relieve anxiety.

2) Seek help from the supporting forces of the surrounding society

External support from family, school, and social environment is of great help to relieve the anxiety of college students. Therefore, these external forces need to carry out regular screening of students' anxiety symptoms, so as to timely discover these high-trait anxiety groups and conduct psychological intervention and exercise interventions for them. In particular, within the scope of epidemic prevention and control, schools need to organize regular and quantitative sports activities in a small range, and open sports venues, such as school football fields, sports equipment, and other sports projects to prevent anxiety.

3) Strengthen psychological quality, face anxiety directly, and strengthen body and heart at the same time

In the final analysis, anxiety is an individual's own psychological emotions in the face of external emergencies or a new environment. Therefore, if college students want to maintain good mental health, what they need to do most is to strengthen their own psychological quality, such as developing their own interests, reading books, keeping themselves busy, making study and life plans, and maintaining an optimistic and positive attitude toward the uncontrollable situation (the change of lifestyle brought by the epidemic).

6. Conclusion

Since the outbreak of COVID-19, the life, study, and work of college students have been affected to varying degrees, and it is inevitable that they will have anxious emotions and even form anxiety disorders. Thereby, the strategies for easing the anxiety of college students in the post-pandemic era are studied. Firstly, anxious emotion and anxiety disorder are defined. Due to diverse psychological anxiety levels, they are treated differently. Secondly, a questionnaire survey is carried out for a well-known university in a certain city. Various questionnaire scales are developed based on the physical exercise, anxiety, social support, and proactive personality evaluation of college students. Finally, according to the results of the survey, it is found that a certain degree of physical exercise has a certain effect on relieving the anxiety of college students, and it is closely related to the social support and personality traits of college students themselves. The conclusion of this study can provide practical significance for the exploration of the mental health of college students. The limitation of this study lies in the limited number of samples collected due to the limitations of conditions, so it cannot fully analyze the psychological conditions of all college students. In addition, this survey mainly focuses on the anxiety of college students, without paying too much attention to other mental health problems, such as depression and tension. Thereupon, it is planned to expand the research scope, further increase the number of samples collected, and expect to obtain more in-depth research results.

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 human participants were reviewed and approved by the Academic Ethics Committee of the School of Psychology at Northeast Normal University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

BS contributed to the conception and design of the study and wrote sections of the manuscript. ML organized the database, performed the statistical analysis, and wrote the first draft of the manuscript. All authors contributed to the manuscript revision, read, and approved the submitted version.

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Conflict of interest

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

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Psychometric properties of the Sport Courage Scale for Chinese athletes

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Objective: To revise *Sport Courage Scale* (SCS) suitable for Chinese athletes.

Methods: Six hundred and eighty three athletes were selected for verification factor analysis, correlation analysis, reliability analysis, and independent sample *t*-test using the method of random sampling of the entire group.

Results: Confirmatory factor analysis model showed that model 1 (25 items) failed to fit the data; while model 2 (20 items) was finally accepted with its five-factor model. The factor structure consists of 5 dimensions (χ^2/df=2.262;CFI=0.969;TLI=0.963; RMSEA=0.043; SRMR=0.044). Cronbach's α of the final version of *SCS* was 0.845, and the corrected correlation coefficient between the items and the total score of the scale was between 0.352 and 0.788.

Conclusion: Revised *SCS* has good reliability and validity and can be used as a measurement tool for the sports courage of athletes in China.

KEYWORDS

Chinese athletes revision, courage, sport courage, SCS, characteristics of psychometrics, exploratory structural equation modeling

Introduction

Courage is a voluntary will to act against threats with varying degrees of fear/without fear to achieve an important moral goal or aim (Woodard and Pury, 2007). Putman (1997) proposed three types of courage, namely physical courage, moral courage, and psychological courage. Physical courage is defined as the action taken in the face of physical danger; moral courage defined as the truth and integrity in the face of danger; psychological courage defined as the action taken regardless of the risks to one's mental health (Putman, 1997). Corlett (1996) believed that courage can be used as a tool to manage and overcome fear, anxiety, tension, and stress in sports. Courage may be related to various popular topics in sports psychology, such as self-confidence, concentration, achievement motivation, competitiveness, psychological resilience, decisiveness, and response to improve motor function and performance (Konter, 2013). As found in the study of Konter et al. (2020a), football players with higher overall courage levels have more sports experience in football. When it comes to courage, experts and scholars in sports have shown the importance of courage to success and operational performance. However, sports courage and related concepts have received little attention (Konter, 2013).

Athletes are a relatively special group and may have high anxiety and depression in different periods, which directly affects athletes' mental state and training. Ping and Qiu (2016) found that people who put themselves in a frightening stimulus or scene to participate in brave behavior have a lower probability of suffering from serious anxiety problems. Mann et al. (2007) found that the three most common non-injury-related topics discussed in the survey of athletes are stress/pressure, anxiety, and burnout. Courage has an important positive influence on

athletes' personality cultivation and coping in daily life (Konter and Ng, 2012). Sports are an essential part of athletes' daily life, so it is necessary to further study athletes' sports courage.

There are many tools for courage measurement. The most common ones are *Personal Perspectives Survey* (Woodard, 2004), *Woodard Pury Courage Scale* (Woodard and Pury, 2007), *Values in Action Inventory of Strengths* (Peterson and Seligman, 2004), and *Courage Measure* (Norton and Weiss, 2009). All the above measure multidimensional courage from different angles, while *SCS* (Konter and Ng, 2012) measures courage in sports. Upon preparation of PPS questionnaires, the subjects are selected from several biased samples with high fear and high willingness to act, and there are items with multiple loads. The overall questionnaire shows good Cronbach's α; however, there may be moral judgment in the courage measurement, which may lead to measurement deviations (Qian et al., 2016).

The controversy with WPCS is that the items in the scale are more related to morality and occupation, and courage is not evaluated as a whole. Moreover, WPSC Cronbach's α of WPSC is 0.683, with three double-load items. As a result, the reliability and validity index of WPCS is not ideal (Qian et al., 2016). Compared with PPS-31, WPCS questions and reliability have been reduced. Besides, questions such as the empirical validity of the questionnaire have yet to be verified (Cheng and Huang, 2014). *VIA*-IS scale is developed under the background of an American individualist culture, so measuring courage with 4 items, including courage, persistence, integrity, and vitality, may not apply to countries with different cultures, especially to Chinese people who have lived in collectivist culture for a long time. The applicability of *VIA*-IS may decline (Cheng and Huang, 2014). The operational definition used in the development of the CM scale makes it have theoretical concerns, and CM may measure the persistence of fear rather than that of courage (Howard and Alipour, 2014). The internal consistency coefficient of CM is 0.92, and the reliability of the retest after 3 weeks is 0.66. The medium level of retest reliability and the relatively small number of questions indicate some instability factors in the use of single-dimensional questionnaires to measure complex courage (Cheng and Huang, 2014).

Konter and Ng (2012) developed SCS suitable for teenagers aged 13–22 to fill the gap in the courage scale before. The scale has been widely used in other cultures and has versions suitable for different ages, with dependable reliability and validity. For example, Cronbach's α of five dimensions of SCS (RSCS-C) for children aged 10–13 is MT = 0.75, DT = 0.76, AT = 0.71, VS = 0.75 and SB = 0.68, which has good structural validity (Konter et al., 2013). The revised version of the *Malaysian SCS* (SCS-M) keeps the same dimensions and adds two items based on the original scale. Cronbach's α of the five dimensions is MT = 0.64, DT = 0.76, AT = 0.71, VS = 0.68, and SB = 0.69, which has acceptable structural validity (Hidrus et al., 2020). Konter et al. (2020b) revised the *SCS* for American college athletes (SCS-AE) and finally retained 24 items in four dimensions. Cronbach's α in four dimensions is MT = 0.73, DT = 0.77, AT = 0.78, and VS = 0.74, which has good structural validity. Therefore, the psychological structure of sports courage may be influenced by culture and age.

Based on the above theoretical basis and practical requirements, it is difficult to directly apply the *SCS* to Chinese athletes. Therefore, the scale needs to be revised for Chinese athletes, and its reliability and validity shall be tested among college students to develop the *SCS* suitable for Chinese athletes.

Materials and methods

Participants

This study protocol has been approved by the Ethics Committee of Shenyang Sport University. A total of 775 college students were enrolled in the work, 683 of whom were included in the samples. The exclusion criteria are samples with incomplete basic information and missing questions. The age ranged from 15 to 24 years old, with an average age of 20.30 years old ($SD = 2.50$) in the valid questionnaire. There were 387 males (56.67%) and 296 females (43.33%). The average length of training was 5.26 years ($SD = 2.59$). Four hundred and seven people (59.59%) have achieved the skill level of athletes and 276 people (40.41%) have not. Sports mainly included skiing, skating, basketball, football, track and field, aerobics, table tennis, tennis, and badminton. Participants must sign an informed consent form.

Measures

Sports courage scale

Konter and Ng (2012) developed the items of Sports courage scale (*SCS*) based on the experience and feeling of sports courage, and the items were generated according to the meaning of sports courage. The scale was divided into five dimensions: Mastery (MT), Determination (DT), Assertiveness (AT), Venturesome (VS), and Self-Sacrificial Behavior (SB). Mastery included 7 items; determination included 9 items; assertiveness included 7 items; venturesome included 4 items; self-sacrificial behavior included 4 items. They formed a total of 31 items (including 7 reverse scoring items; Konter and Ng, 2012). 5-point Likert scale was adopted for SCS, with 1 = "Totally disagree" and 5 = "Totally agree." High scores indicated high sports courage.

Courage measure

Courage measure (CM) compiled by Norton and Weiss (2009) contains only one dimension, that is, persevering in moving forward despite experiencing fear. The questionnaire contains 12 question items, and the scores of each question item range from 1 = "Never" to 7 = "Always." The higher the total score, the higher the level of courage.

Simple grit scale

Duckworth's research team (Duckworth et al., 2007) revised and compiled grit scale (Grit-S). The scale is divided into two component tables including consistency of interest (CI) and persistence of effort (PE), with 8 items. The four items in the persistent effort dimension are scored in reverse. Likert's 5-point scoring is used, 1 = "Completely inconsistent" and 5 = "Fully consistent." A high score represents a high degree of perseverance.

Procedure

The work was authorized by Dr. Erkut Konter to revise SCS. SCS was first translated into Chinese by 2 college English teachers and 1 graduate student in sports psychology in this scale, respectively. The translations of the above 3 people were integrated and compared, and an agreement was reached after discussion to form the first draft of the Chinese version of *SCS*. Then, the first draft of the Chinese version of

SCS was retranslated into English by 1 college English teacher and 1 graduate student majoring in English without reading *SCS*. We compared the translated English with the original text, modified the items with great differences in translation, and further improved the accuracy of the questionnaire translation. Finally, two Chinese psychological professors and several psychological graduate students were asked to evaluate the validity of the content so that it could combine Chinese culture and semantics in terms of expression habits and life customs. This was to ensure that the Chinese version was consistent with the meaning expressed in the original scale so that it conformed to Chinese culture and semantics in terms of expression habits and living customs. Twenty-three Chinese athletes were randomly selected to complete the scale because they would understand. In the end, the final questionnaire was prepared.

Then the formal test was carried out with the questionnaire. First of all, on the front page of the electronic questionnaire, all athletes who took the test filled out an informed consent form. Secondly, athletes were asked to provide demographic data. Finally, they were asked to complete the questionnaire. The data collection process was undertaken by several graduate students in psychology. Questionnaires were collected by the principal investigators after the completion of the survey.

The investigators recruited 143 athletes offline in Shenyang Sport University, and they completed SCS twice in 3 weeks. These questionnaires were used to test the test–retest reliability of the scale.

Data analysis

SPSS 23.0 and Mplus 8.0 were used to analyze the data. Project analysis was used to examine the degree of discrimination of projects. Internal consistency reliability coefficient and halved reliability coefficient were used for reliability analysis. Structural validity was tested by exploratory structural equation modeling (ESEM; Asparouhov and Muthén, 2009). Some common fitting indices were used to determine the fitting degree of the model, including Chi-square goodness-of-fit statistics, comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR).

Results

Project analysis

We initially calculate corrected item-total correlation *r* (Chen et al., 2015). *r* refers to the correlation coefficient between the scores of each item and the total score of the remaining items in each dimension. *r* of the items in MT is 0.326–0.788. *r* of items in DT is 0.202–0.425, and *r* of items 12 and 17 is 0.202 and 0.214, respectively. *r* of items in AT is 0.119–0.660, and *r* of items 3, 8, and 13 is 0.241, 0.119, and 0.224, respectively. *r* of items in VS is 0.622–0.777. *r* of items in SB is 0.073–0.627, and *r* of item 31 is 0.073. *r* of items 3, 8, 12, 13, 17, and 31 are less than 0.300, and *r* of all the other items is greater than 0.300 (see Table 1). Then, item-total correlation is calculated (Hao and Hong, 2014).

Item-total correlation *r* refers to the correlation between the item and the total score of the corresponding dimension. The correlation coefficient between the total score of MT and the items in the dimension table is between 0.470 and 0.857, with $ps < 0.01$. The correlation coefficient between the total score of DT and the items in the dimension is between 0.402 and 0.588, with $ps < 0.01$. The correlation coefficient between the total score of AT and each item in this dimension is between 0.368 and 0.780, with $ps < 0.01$. The correlation coefficient between the total score of VS and each item in this dimension is between 0.789 and 0.879, with $ps < 0.01$. The correlation coefficient between the total score of SB and the items in this dimension is between 0.421 and 0.818, with $ps < 0.01$. All values are greater than 0.3. Finally, respondents were grouped according to the top and bottom 27% of the total score of each dimension. An independent sample *t*-test was used to compare the scores of the high and low groups of each item, and significant differences existed in all items (see Table 1).

The corrected item-total correlation, extreme grouping independent sample *t*-test, and item-total correlation are recalculated after deleting items 3, 8, 12, 13, 17, and 31. The corrected item-total correlation of DT, AT, and SB is 0.352–0.452, 0.682–0.738, and 0.612–0.681, respectively. The correlation coefficient between the total score of DT and the items in the dimension is between 0.561 and 0.631, with $p < 0.01$. The correlation coefficient between the total score of AT and each item is between 0.824 and 0.856, with $p < 0.01$. The correlation coefficient between the total score of SB and items is between 0.837 and 0.862, with $p < 0.01$. All the items in the scale are of good discrimination after deleting the above six items, so items 3, 8, 12, 13, 17, and 31 are considered to be deleted.

Validity analysis

Exploratory structural equation modeling

A five-factor model of the original data was established after reverse-scoring related items. A first-order five-factor model is set for the original design theory of the questionnaire, including mastery (factor I), determination (factor II), assertiveness (factor III), venturesome (factor IV), and self-sacrificial behavior (factor V). Table 2 introduces the fitting index of the ESEM model. The fitting index shows that Model 1 (25 items) cannot fit data well. The factor load values of items 22, 25, 27, 28, and 30 are 0.062, 0.039, 0.346, 0.148, and 0.066 (Table 3). According to the correction of the model (Bagozzi and Heatherton, 1994; Liu, 2019), the topics of small load values can be deleted based on the load values of factors (threshold < 0.5). Therefore, items 22, 25, 27, 28, and 30 are to be deleted. The items in bold were retained.

Verification factor analysis is performed again after deletion. Table 2 shows the fitting indices of model 2 (20 items): χ^2/df is less than 3; CFI and TLI are greater than 0.90; RMSEA and SRMR are less than 0.05. These fitting indices all meet the requirements of psychometrics (Mai and Wen, 2013), indicating that the fitting indices of model 2 are more ideal (see Figure 1). Average variance extracted (AVE) of model 2 and the composite reliability (CR) are ideal (Fornell and Larcker, 1981; see Table 4 for the results).

Empirical validity

Empirical validity is also called predictive validity. Grouping was performed according to the presence or absence of exercise level. Then an independent sample *t*-test was used to compare the differences between the total scores of different grouping scales. The results showed that the total score of *SCS* in different groups was significantly different. $t = 2.446$ and $p < 0.05$, indicating that the scale has good empirical validity.

TABLE 1 Results of corrected item-total correlation *r*, independent sample *t*-test, and standardized factor load.

Item	Project content	Corrected *r* before deletion	Corrected *r* after deletion	*t* before deletion	*t* after deletion	Factor loading
1	遇到困难时, 我会害怕失败。(When faced with a difficult situation, I experienced a fear of failure.)	0.719**	0.719**	0.811**	0.811**	0.805
6	害怕使我很少获得比赛胜利。(I have limited success because I get frightened.)	0.788**	0.788**	0.857**	0.857**	0.859
11	在比赛中，我经常会夸大困难。(I exaggerate difficulties.)	0.714**	0.714**	0.800**	0.800**	0.805
16	对自己能力的怀疑让我不能取得比赛胜利。(My doubts about my abilities keep me from success.)	0.715**	0.715**	0.797**	0.797**	0.800
21	缺乏自信让我错失了很多机会。(My lack of self-confidence makes me miss opportunities.)	0.710**	0.710**	0.792**	0.792**	0.790
24	当面临困难时，我会变得很悲观。 (I become pessimistic when faced with difficulty.)	0.742**	0.742**	0.821**	0.821**	0.810
27	在困难的情况下，我会选择逃避。(When I am in a difficult situation I take the easiest option.)	0.326**	0.326**	0.470**	0.470**	-
2	我不会逃避挑战强大的对手。(I do not avoid challenging strong opponents.)	0.367**	0.352**	0.549**	0.561**	0.853
7	我是一个相信任何事情都可以实现的人。 (I am a person that believes anything can be achieved.)	0.381**	0.372**	0.553**	0.569**	0.836
12	我会努力证明没有什么好害怕的。 (I struggle to demonstrate that there is nothing to fear.)	0.202**	-	0.411**	-	-
17	我能积极主动地面对困难。(I do not avoid taking the initiative when faced with difficult conditions.)	0.214**	-	0.402**	-	-
20	不管当前情况有多不利，我也会尽我最大的能力。(I perform to the best of my ability not matter how negative the current conditions.)	0.376**	0.372**	0.547**	0.568**	0.834
22	我会竞争到最后而不害怕失败。 (I compete until the end without worrying about failure.)	0.361**	0.385**	0.549**	0.593**	-
25	我觉得我有实力在困难的条件下取得比赛胜利。(I feel that I have the strength to be successful in difficult conditions.)	0.347**	0.366**	0.531**	0.572**	-
28	即使遇到困难，我也会很自信。(I am assertive even in difficult conditions.)	0.425**	0.452**	0.588**	0.631**	-
30	即使有压力，我也不会忘记自己的目标。(Even when under pressure I do not lose sight of my goals.)	0.380**	0.401**	0.553**	0.593**	-
3	在比赛中，我能轻松应对对手的进攻。 (It is easy for me to overcome my opponent's attacks.)	0.241**	-	0.448**	-	-
8	我喜欢积极主动地面对困难。(I like to take initiative in the face of difficulties.)	0.119**	-	0.368**	-	-
13	在比赛中，我能应对对手的突然进攻。 (I have no problems responding to opponents' sudden attacks.)	0.224**	-	0.459**	-	-
18	我善于在遇到困难时寻找解决问题的办法。(I am good at finding solutions to problems in difficult conditions.)	0.660**	0.738**	0.789**	0.856**	0.837
23	即使面对危险，我也会坚持自己完成比赛(任务)。(I assert myself even when facing hazards.)	0.602**	0.682**	0.740**	0.824**	0.813
26	即使面对危险，我也会从容镇定地继续比赛。(I continue to compete without panicking even when faced with a danger.)	0.594**	0.731**	0.736**	0.855**	0.857

(Continued)

TABLE 1 (Continued)

Item	Project content	Corrected *r* before deletion	Corrected *r* after deletion	*t* before deletion	*t* after deletion	Factor loading
29	遇到困难时，我不会推卸责任。(In difficult situations I do not shirk responsibility.)	0.576**	0.721**	0.721**	0.847**	0.852
4	为了不输掉比赛，我会冒着受伤的风险 。(I risk injury in order not to lose.)	0.644**	0.644**	0.811**	0.811**	0.785
9	我甘愿冒任何受伤的风险以取得比赛胜利。(I would take any type of risks to become successful.)	0.642**	0.642**	0.806**	0.806**	0.763
14	即使面对危险的情况，我也会去挑战。(I do not avoid a challenge even when facing a dangerous situation.)	0.777**	0.777**	0.879**	0.879**	0.884
19	即使面对受伤的可能，我也会尽我最大的能力。(Even when facing the possibility of injury, I perform to the best of my ability.)	0.622**	0.622**	0.789**	0.789**	0.774
5	即使有失败的可能性，我也会毫不犹豫地去参加比赛。(I do not hesitate to compete, even when facing the possibility of defeat.)	0.627**	0.681**	0.818**	0.862**	0.850
10	即使这个动作(练习)对我可能有害，我也会坚定目标拼到最后。(I defend my beliefs until the end even if this action might prove harmful to me.)	0.537**	0.612**	0.777**	0.837**	0.761
15	我可以接受他人对我的原则或信念的批评。(I can take criticism of my principles or beliefs.)	0.570**	0.646**	0.779**	0.839**	0.851
31	即使失去的比得到的要多，我也会去完成比赛。(I compete even if I have much more to lose than to gain.)	0.073**	-	0.421**	-	-

**$p < 0.01$; ***$p < 0.001$. Mastery: items 1, 6, 11, 16, 21, 24, and 27. Determination: items 2, 7, 12, 17, 20, 22, 25, 28, and 30. Assertiveness: items 3, 8, 13, 18, 23, 26, and 29. Venturesome: items 4, 9, 14, and 19. Self-sacrificial behavior: items 5, 10, 15, and 31.

TABLE 2 Goodness of fit and indices of different SCS models.

Model	χ^2	*df*	χ^2/df	CFI	TLI	RMSEA	SRMR
Model 1	1798.043***	265	6.785	0.805	0.779	0.092	0.099
Model 2	361.944***	160	2.262	0.969	0.963	0.043	0.044

***$p < 0.001$.

Criterion-related validity

CM and Grit-S were selected as the validity questionnaire, and criterion-related validity was tested on the overall sample. The results showed that the total score of SCS was positively correlated with the total scores of CM and Grit-S. Exercise courage was positively correlated with courage and perseverance (see Table 5 for the results).

Discriminant validity

The five dimensions of SCS were tested for discriminant validity. Heterotrait–monotrait ratio (HTMT) was used for testing in the work. The HTMT results between dimensions were all less than 0.85, indicating a distinction between all dimensions (Henseler et al., 2015; see Table 6 for the results).

Reliability analysis

Reliability analysis showed that Cronbach's α of the five dimensions of SCS was MT = 0.905, DT = 0.817, AT = 0.867, VS = 0.839, and SB = 0.802. Cronbach'sα of the total scale was 0.845, and McDonald's Omega ω of SCS is 0.868. The split-half reliability of the five dimensions was as follows: MT = 0.903, DT = 0.822, AT = 0.861, VS = 0.839, and SB = 0.801. The split-half reliability of the total scale was 0.920.

Discussions

The work applied SCS to Chinese athletes to assess whether it could accurately assess the level of sports courage of Chinese athletes. The results showed that the reliability and validity of SCS (Chinese version) were satisfactory. SCS (Chinese version) contains 20 projects and five dimensions [Mastery (MT), Determination (DT), Assertiveness (AT), Venturesome (VS), and Self-Sacrificial Behavior (SB)]. The factor structure of SCS was confirmed by structural equation model. The item analysis shows that the remaining 20 items are of good item discrimination. The internal consistency reliability coefficients in each dimension of the scale are 0.905, 0.817, 0.867, 0.839, and 0.802, respectively, and the internal consistency reliability coefficient of the total scale is 0.845. The split-half reliability of each dimension is 0.903, 0.822, 0.861, 0.839, and 0.801, and that of the total scale is 0.920. The retest

TABLE 3 Factor load values of model 1.

		Estimate	S.E.	Est./S.E.	Two-tailed *P*-value
MT	BY				
1		**0.769**	**0.018**	**43.009**	**0.000**
6		**0.852**	**0.013**	**64.568**	**0.000**
11		**0.771**	**0.018**	**43.274**	**0.000**
16		**0.760**	**0.018**	**41.335**	**0.000**
21		**0.757**	**0.019**	**40.808**	**0.000**
24		**0.788**	**0.017**	**46.739**	**0.000**
27		0.346	0.036	9.729	0.000
DT	BY				
2		**0.774**	**0.023**	**34.293**	**0.000**
7		**0.747**	**0.023**	**31.877**	**0.000**
20		**0.795**	**0.022**	**35.669**	**0.000**
22		0.062	0.043	1.446	0.148
25		0.039	0.043	0.916	0.360
28		0.148	0.042	3.491	0.000
30		0.066	0.043	1.523	0.128
VS	BY				
4		**0.717**	**0.022**	**32.065**	**0.000**
9		**0.732**	**0.022**	**33.847**	**0.000**
14		**0.881**	**0.016**	**56.162**	**0.000**
19		**0.693**	**0.023**	**29.614**	**0.000**
SB	BY				
5		**0.808**	**0.023**	**35.909**	**0.000**
10		**0.724**	**0.026**	**28.278**	**0.000**
15		**0.745**	**0.024**	**31.168**	**0.000**
AT	BY				
18		**0.820**	**0.017**	**47.187**	**0.000**
23		**0.744**	**0.021**	**35.824**	**0.000**
26		**0.800**	**0.018**	**44.079**	**0.000**
29		**0.787**	**0.019**	**42.070**	**0.000**

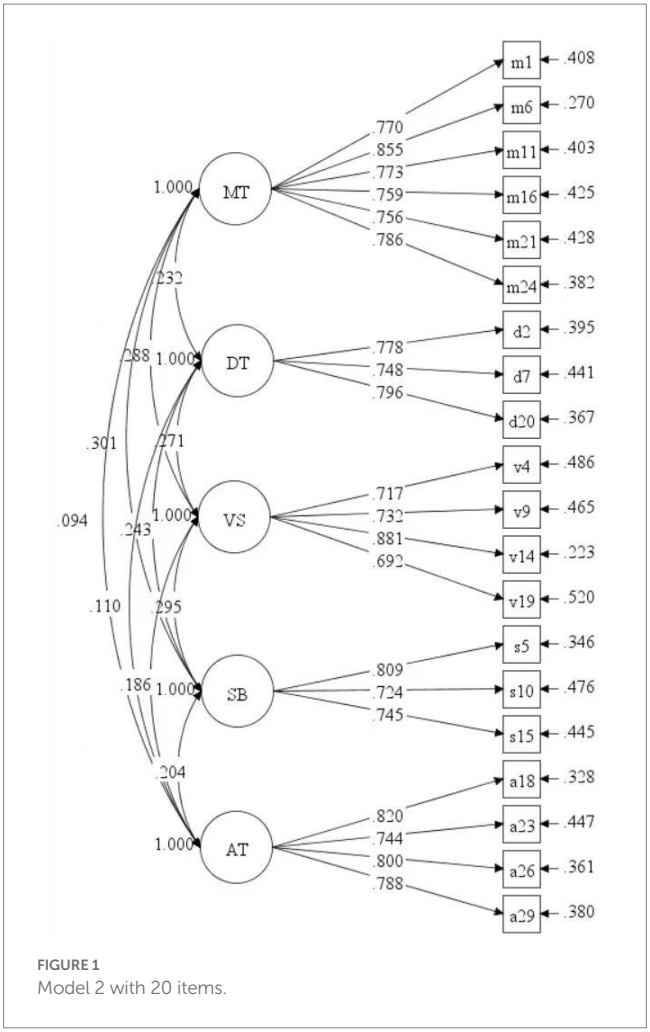

FIGURE 1
Model 2 with 20 items.

TABLE 4 Model reliability and composite reliability.

Factor	AVE	CR
MT	0.614	0.905
DT	0.599	0.818
VS	0.576	0.844
SB	0.578	0.804
AT	0.621	0.868

correlation of the scale is 0.948, which can meet the psychometric standard. Factor analysis shows that the internal structure of the revised questionnaire is consistent with that of the original one. The fitting indices of the corrected model show that χ^2/df is less than 3; CFI and TFI are greater than 0.90; RMSEA and SRMR are less than 0.08. Therefore, all fitting indices meet the psychometric standards, and the scale shows a clear structure.

Compared with the original version of the courage scale, the dimensions of SCS for Chinese athletes were consistent with those of the original scale (Konter and Ng, 2012). However, only 20 items in the original scale were retained, and these deleted items might be deleted due to the differences between China and Turkey. Group differences appeared for Chinese athletes during filling out questionnaires because of the influence of different countries in China and Turkey on the differences in athlete training models. Since the questionnaire for the work was only distributed in the north of China, regional differences in China had certain influences. Besides, the proportion of subjects might be a reason. There were 407 subjects with exercise levels in the work, which accounted for 59.59%. However, professional athletes accounted for less than 10% of the subjects of the initial version of SCS.

An interesting finding is that significant gender differences are found in MT. Male athletes score higher than female athletes in MT and SCS. The findings are consistent with the results of previous studies (Konter, 2016). Another previous study found that women's emotions are stronger, last longer, and express more clearly; while men are more rational and can better control their emotions (Brody and Hall, 2008). There is a highly positive correlation degree between exercise level and exercise courage. Therefore, we should pay attention to how to improve courage

TABLE 5 Correlation coefficients among SCS, CM, and Grit-S.

	1	2	3	4	5	6	7	8	9	10
1. MT	1									
2. DT	0.196**	1								
3. VS	0.254**	0.242**	1							
4. SB	0.270**	0.203**	0.267**	1						
5. AT	0.076*	0.089*	0.171**	0.171**	1					
6. SCS	0.744**	0.495**	0.636**	0.569**	0.470**	1				
7. CM	0.293**	0.236**	0.276**	0.233**	0.222**	0.426**	1			
8. CI	0.279**	0.259**	0.262**	0.289**	0.273**	0.448**	0.184**	1		
9.P E	0.238**	0.271**	0.294**	0.308**	0.264**	0.442**	0.135**	0.486**	1	
10. Grit-S	0.301**	0.307**	0.323**	0.346**	0.312**	0.517**	0.186**	0.865**	0.859**	1

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

TABLE 6 HTMT results.

	MT	DT	VS	SB	AT
MT	-				
DT	0.229	-			
VS	0.292	0.292	-		
SB	0.312	0.250	0.322	-	
AT	0.086	0.106	0.200	0.206	-

through exercise in future research. Significant differences exist in sports courage between athletes in winter sports and summer sports. A previous study found that compared with cross-country skiers, marathon runners look smarter and tougher on 16 Personality Factor Inventory (16 PF). They are more subjective, creative, and academic on derivative factors (Jerome and Valliant, 1983). Therefore, in future research, we should pay attention to the personality differences between athletes in summer and winter.

Grit-S and *CM* were used as questionnaires to test the criterion-related validity of *SCS*. The results showed a significant positive correlation between SC and perseverance. Perseverance refers to passion and persistence in long-term goals (Duckworth et al., 2007). Perseverance can be understood as promoting sports professional skills by extending time to participate in and adhere to practical activities (Hodges et al., 2017). Schimschal et al. (2022) established a psychological-resource model of perseverance. Interest is defined as a psychological resource of perseverance, which enables a person to explore and deepen their interests through attributes such as curiosity, self-awareness, courage, and patience. A study by Howard and Cogswell (2019) also showed that behavioral social courage is positively correlated with perseverance. Besides, the results show that the five dimensions of *SCS* are significantly positively correlated with courage.

The revised version of *SCS* for college athletes combined with American college students only retains 24 items in four dimensions of the original scale (Konter et al., 2020b). In this regard, it is reasonable to delete the items in the revised version of SCS for Chinese athletes. Gauvin et al. (1993) found that there may be serious misinterpretations and errors in the test. Besides obvious language differences, even if the test content is accurately translated, subtler cultural differences affect the test results.

In conclusion, the revised version of SCS is of good reliability and validity and can be used as a tool to measure the sports courage of Chinese athletes.

Limitations and future directions

There are limitations in this study. (1) A self-reporting method is used, so these results may be affected by the effect of social identity. However, the work aims to develop a reliable and effective tool. (2) Athletes are selected as participants, but non-clinical samples are used. Clinical samples will be selected from athletes to expand the applicability of the scale. (3) Samples are relatively small and may not represent all Chinese athletes. Larger samples are needed for further evaluation in the future.

The findings have some practical significance. The work has taken the first step in applying SCS to Chinese. Future studies will use a wider range of athletes as participants, and it is recommended to check their reliability and effectiveness. Besides, there are significant differences in sports courage between athletes in summer and winter as well as between sports levels and non-sports levels. Athletic courage can be cultivated from exercise methods to enhance overall courage, which has a profound impact on individual development.

Data availability statement

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

Author contributions

SG reviewed the literature and wrote the manuscript. SG, ZG, and RZ analyzed and dealt with the data. SG, RZ, and JJ Collected

questionnaires. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1133720/full#supplementary-material

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Contemporary practices of physical trainers in professional soccer: A qualitative study

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Introduction: Physical trainers (PTs) are integral for managing load, reducing injury and optimizing performance in professional soccer. However, little is known about how this practitioners operate in the applied setting and how some of the nuances experienced influence practice.

Methods: This study explored the contemporary practices of PTs in professional soccer. Semi-structured interviews were undertaken with eight PTs from different professional teams in European and South American leagues. Interview questions were designed to extract information on the evaluation of physical abilities, monitoring and control of training and injury prevention. Subsequently, the interviews were video-recorded, transcribed, translated and analyzed using a content analysis approach.

Results: The results suggest that the evaluation of physical capacities is carried out by PTs at the beginning of the preseason. It also appears that it is attempted that this process of regular testing is applied during the competitive period, with most participants conducting partial physiological and physical evaluations at different stages throughout the competitive season. In relation to the monitoring and control of training, subjective feedback scales are used to estimate the internal load, and the use of GPS devices is common to quantify external loads. Injury prevention programmes were implemented by all participants and were generally in a multi-component format focused on preventing or optimizing physical capabilities.

Discussion: These insights can be used as a scientific reference point to inform applied practice in professional soccer, especially for practitioners that are inexperienced and aspiring to enhance how they operate in the field. Future investigations should explore the practices of PTs in detail and across a wider network in order to gain deeper and comprehensive insights into the applied soccer environment.

KEYWORDS

physical abilities, evaluation, monitoring and control, injury prevention, optimization, professional football

1. Introduction

Soccer is characterized as a high-intensity, intermittent team sport with many games across a competitive season (Turner and Stewart, 2014; Konefal et al., 2018). Professional soccer physical trainers (PTs) must use their understanding and experience of sports science and training to optimize physical and athletic performance while reducing injury risk (Weldon et al., 2021). Such expert sports science support ensures professional soccer players continue to develop and maintain a high level of conditioning during the season (Turner and Stewart, 2014). It is key that this process is optimized to enhance performance (Bangsbo, 2014; Turner and Stewart, 2014; Slimani and Nikolaidis, 2017; Ribeiro et al., 2021); however, there is less research to facilitate the understanding of how PTs operate within the applied environment. Contemporary research has surveyed strengths and conditioning practitioners (Weldon et al., 2021); however, this research mainly included European practitioners and used survey methods with critics arguing that insights lack key details that might be captured during interviews (Bailer, 2014). Therefore, it appears warranted to obtain a deeper understanding of applied practice across several continents to design and implement periodized training plans (Bompa and Buzzichelli, 2019).

The role of the PTs is complex and multifaceted, with the role including the development and maintenance of strength and endurance capabilities for optimal performance (Jones et al., 2013). The planning involved across an entire season includes optimizing both performance and recovery (Impellizzeri et al., 2004; Gaudino et al., 2015b; Moalla et al., 2016), in addition to ensuring an ideal workload to minimize injuries (Jaspers et al., 2017). To achieve this balance, adaptations to the volume and intensity of training must be made around matches, facilitating harmony between adaptations and recovery (Springham et al., 2018). It may also be necessary to individualize training loads due to the differences in individual training history, physical condition, body composition, strength asymmetries, and injury history (Bahr and Tron, 2005). Different internal and external load monitoring tools are commonly used both in training and competition (Newton et al., 2019). To estimate the internal load, tools such as the subjective perception of effort are currently used (Gabbett and Whiteley, 2017), and objective measures of exercise intensity, such as autonomic heart rate regulation indices (exercise heart rate) (Ali and Farrally, 1991) or biochemical markers (creatine kinase [CK]) (Lazarim et al., 2009a; Ribeiro et al., 2022), are also currently used. For external load, the most used tools are tracking systems (global positioning systems [GPS]) (Weldon et al., 2021), and these parameters provide information on work performed by each individual player. This information allows the PTs in professional soccer to make informed decisions regarding the timing of training sessions (Newton et al., 2019). However, it is precisely unclear how these methods are adopted to inform periodization and strength and conditioning programs.

Injury prevalence is high in professional soccer (Pérez-Gómez et al., 2020) and has a detrimental economic impact, particularly since player inactivity results in additional costs for medical treatment and influences team selection and player availability (Ekstrand, 2016). This in turn reduces team success both in the league and international competitions (Hägglund et al., 2013). As such, the implementation of prevention programs aims to reduce the negative implications of injury and consequently increase sporting success (Hägglund et al., 2013). Due to the importance of PTs in enhancing performance and minimizing injury, the objective of this study is to investigate the contemporary practices of PTs in professional soccer across two continents. This will help identify the methodologies used in the assessment of physical capabilities, monitoring and control of training, and injury prevention which will support the development of applied research and practice. In addition, the knowledge gained can provide a source of information for trainee PTs, with the data also being able to be used for current PTs for their practices.

2. Material and methods

The participants were asked to describe their practices and opinions, with the aim of providing an understanding of their knowledge and practices in professional soccer. The semi-structured interview script was submitted for review by five sports science experts. All reviewers were contacted *via* email and included the following: three reviewers with PhDs in sports science (two with experience in qualitative research design) and two reviewers presently operating as PTs. A pilot interview was also carried out with a PT. Minor modifications to the wording and organization of the survey were made to the interview questions following review and pilot testing to avoid conceptual ambiguities and ensure validity. Finally, the pilot test was incorporated into the analyses. The interview consisted of the following three sections: (1) evaluation of physical capacities; (2) training monitoring and control; and (3) injury prevention. The interview answers were all open and the PTs were able to share experiences and opinions on each of the questions. The study was carried out in accordance with the ethical standards of the Declaration of Helsinki and was approved by the scientific council and the ethics committee of the University of Coimbra (CE/FCDEF-UC/00692021).

Initially, 10 professional men's soccer PTs (Europe and South America) were contacted *via* email or telephone during the recruitment process. Of those 10 PTs, eight responded positively and agreed to participate in this research. Before conducting the interviews, all participants signed an informed consent agreeing to participate in the research and their interview was video-recorded. All interviews were conducted during January 2022 (the middle of the season for the European teams and the beginning of the season for the South American teams) and by the same researcher (JB). The PTs had a mean age (37.5 ± 5.8 years) with vast experience working in professional soccer (14.8 ± 6.4 years of experience). The participants had degrees in physical education ($n = 7$) and physiology ($n = 1$), and all had a master's degree or equivalent ($n = 8$), with some also possessing a doctorate ($n = 3$).

To be able to participate in this study, the PTs had to be working in a professional club at the time of data collection (first or second division and/or national team). Once eligibility and consent were obtained, participants engaged in a one-on-one semi-structured interview. Only entire interviews that were conducted from start to finish were used for analyses. The interview began with an explanation of the purpose, topics, estimated duration, and the anonymity of the information and its use (questionnaire available in Supplementary material). Each participant partook in an interview conducted *via* Zoom with the principal investigator, which lasted between 60 and 90 min (some interviews were prolonged since a few PTs provided lengthier responses to the questions). The structure remained similar for all interviews.

To process the results, the qualitative content analysis technique was used to understand how the theory is applied in professional

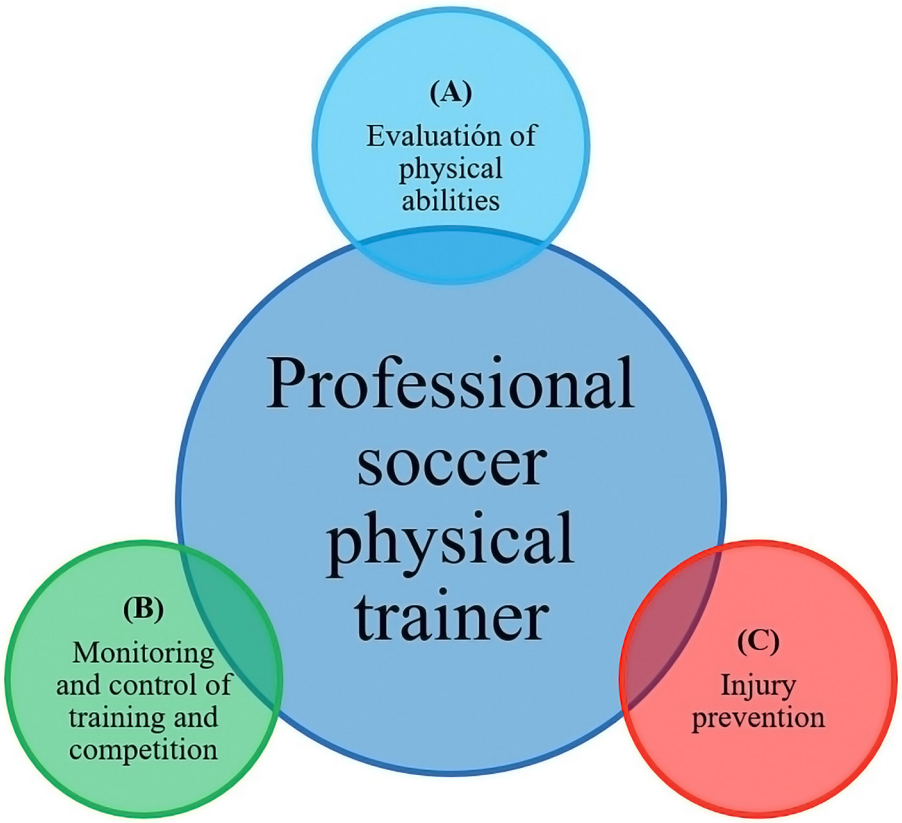

FIGURE 1
Dimensions that make up the work of the professional soccer physical trainer **(A)** Evaluation of physical abilities; **(B)** Monitoring and control of training and competition; and **(C)** Injury prevention.

practice. All interviews were transcribed into a Word 2019 document (Microsoft Corporation, Redmond, WA) and coded using a deductive-inductive approach. The transcripts were read repeatedly to promote data familiarization and immersion in the underlying content (Creswell, 2007). The coding was based on a tree of nodes that was built to reflect the working models (Figure 1) (Côté et al., 2005; Fraser-Thomas et al., 2008; Henriksen et al., 2010, 2011; Davids et al., 2017) and mainly involved higher order issues. Similar to methodologies used previously, inductive coding expanded the node tree when new categories or ideas emerged; such categories and ideas primarily involved low-order topics and the content of topics (2010). The interviews and notes were then subjected to meaning condensation, in which participants' statements were condensed into precise formulations and a summary was written for each node. The QSR NVivo version 12 software was used to code the interview transcripts.

In this study, different techniques were used to establish reliability. The principal investigator received training in qualitative research methods described by several academic sources (Côté et al., 1993; Lincon, 1995; Creswell, 2007; Smith and Caddick, 2012). Member checks (i.e., the data were returned to participants to check for accuracy and resonance with their experiences) were undertaken to establish data credibility (Lincon, 1995). These checks occurred twice in the present study. The first took place during the information session that occurred at the end of each interview. At this point, participants were allowed to change any of their responses. The complete verbatim transcript of each interview was also sent to the participants for their final approval. At this point, the participants had another chance to clarify, add to, or delete any comments they had made during the interview. In addition, the intrapersonal reliability of the data was ensured by a panel of three experts in qualitative methodology who analyzed all units of meaning, themes, and categories.

3. Results

The eight participants worked for a club that competed in professional leagues on one of the two continents, namely, Europe ($n = 4$) and South America ($n = 4$). The main themes resulting from the qualitative content analysis are presented below.

3.1. Evaluation of physical abilities

3.1.1. Relevance of carrying out evaluations for physical capacities

Regarding the *"Relevance of carrying out evaluations for physical capacities"*, we verified that it is a frequent process applied by PTs, who subjectively based on their beliefs, anecdotal experiences, and

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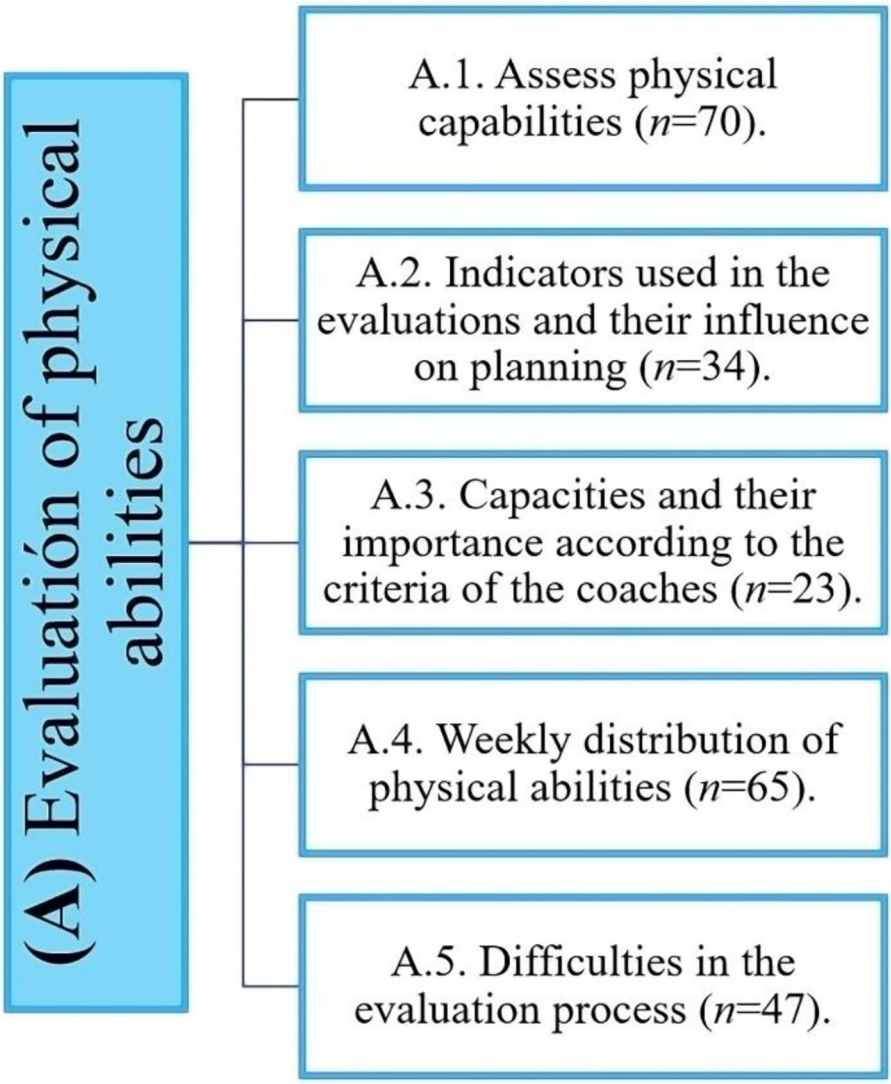

FIGURE 2
Distribution of the evidence obtained in the evaluation of physical abilities.

methodological preferences perform different evaluations that allow them to objectively measure and prescribe optimal training loads for their players (Figure 2).

> Yes, always use tests to evaluate (...) with the objective above all to be able to prescribe training with more rigor, that was always the concern.
>
> PT 6

As for the *"time of evaluations"*, PTs attempt to carry out evaluations at different times, such as the first at the beginning of the season (during the first or second week so as not to expose the players to maximum efforts), then again in the middle of the season (holidays), and lastly, at the end of the season, which in some cases may be conditioned by the decisions of the head coach's or the continuity of the players in the squad (contract termination and team changes).

> (…) I do these diagnostic evaluations in the second week after a fitting so as not to subject the players to maximum effort after the holidays.
>
> PT 2

In contrast, some PTs use partial evaluation strategies with sub-maximal evaluations or tests that do not generate great physical stress on the players. The aim of such work is to gradually adjust the prescription of training loads and limit the additional burden of training sessions, thus not retracting from the time when the head coach must implement their tactical strategy for the next match.

> Another thing that I find interesting are the sub-maximal tests that I have already used many times, which are very easy to apply and are not so subject to this calendar variability, because they can be done in the initial part of the warm-up.
>
> PT 7

Finally, "the physical tests that are used by PTs to determine the physical condition of the players" and that were considered *a priori* at the time of construction were anthropometry, agility, speed, aerobic capacity, anaerobic capacity, strength, and flexibility. The answers provided blood tests as an option *a posteriori*. The tests for anthropometry consist of the assessment of body mass, height, and the sum of six skinfolds. For agility, participants used the Illinois agility test and *t*-tests. The speed tests are linear and vary between 5, 10, 20, and 30 m. Aerobic capacity is estimated through evaluations of direct consumption and carried out in the laboratory with a maximum progressive test and in the field using the 30-15, the Yo-Yo test (both level 1 and 2 variations), or the 1,200 m test. Anaerobic capacity is determined by the 35-m Running-based Anaerobic Sprint Test (RAST), but there are others who do not consider it a necessary evaluation and do not perform it. Flexibility or range of motion is determined by the Functional Movement Screen (FMS). Force is determined using isokinetic tests to determine peak concentric and eccentric torque, as well as the Isometric Mid-Thigh Pull (IMTP). In addition, the neuromuscular performance of the lower limbs is determined through different jump evaluations such as the squat jump (SJ) and countermovement jump (CMJ). Finally, for the upper limbs, only one trainer indicated evaluating the maximum repetition test (RM) using the bench press.

> (…) we performed some muscle function and neuromuscular performance tests such as the SJ and CMJ, isokinetic, then some dynamometry tests in an isometric regimen more related to hip abduction and abduction, and then a more general test that is related to very well with the performance that is the Isometric Mid-Thigh Pull (IMTP).
>
> PT 8

In this same context, but using other reference indicators such as blood markers, PTs use these evaluations to determine muscle damage or stress level of the players before the start of the season or during periods of high match congestion, among other factors.

> (...) I ask a laboratory technician to carry out blood tests to see how the players are when they arrive, to see if they are overstimulated, overtrained, stressed or not, based on being able to have this week of recognition from the players (...) I measure creatinine, ammonium, which are the stress hormones that tell you, look, this player is overtrained, you have to give him a break or, on the other hand, this player has not been stimulated for several weeks or a month.
>
> PT 4

3.1.2. Indicators used in the evaluations and their influence on planning

The use of data was diverse across participants and often depended on the preferences of each PT. In some cases, the use of information for planning ahead was to determine reference values at the beginning of the preseason process to inform subsequent training processes. This also included who should remain in the squad from the previous year or obtain a baseline for the new players. These data enabled comparisons later in the season to assess progress and highlight potential injury risk. Despite the intention of the PTs in the current study attempting to conduct end-of-season testing, there seems to be a consensus that it is challenging, given the high turnover of players and the accumulation of changes at the club.

> (...) this helps us to have a diagnosis to know how they arrived, how the reinforcements are located, how they are located in the group.
>
> PT 2
>
> (...) the great objective is to try to determine if there is any type of muscular deficit in relation to one member to another.
>
> PT 5

The information collected and analyzed allows decisions to be made that help to set goals or adjust training loads, mainly individually or by position, understanding that the demands in each positional role are different. Therefore, complementary work can be designed for the main training session, which is carried out according to their complexity before or after training, trying not to interfere with the work of the head coach, nor with the physical performance of the player.

> Those who are above the average usually do maintenance work and those who are below average do complementary work logically associated with the metrics.
>
> PT 6

3.1.3. Capacities and their importance according to the criteria of the PT

Determining the importance of each physical component of the players is highly complex. If it was necessary to separate and analyze each one of the abilities according to their importance in the players' performance, two preferences were presented for the PTs: (1) strength is considered the most important capacity and it is the one that allows the achievement of greater sports performance. In addition, strength is a facilitating capacity for others such as speed and resistance; and (2) the importance of aerobic capacity is also highlighted due to the benefits it provides for rapid recovery after maximum effort, increased ability to repeat and tolerate these demands, and delayed the onset of fatigue and, in addition, its importance as a protective element to avoid injury.

> Yes, strength (...) as a basic physical capacity, when we develop it, we know that we have greater contractile capacity, therefore, we are going to improve speed levels, we also have greater mitochondrial capacity, which is also going to help us with resistance.
>
> PT 4

Another element that was considered relevant at this point is the mental capacity or cognitive and emotional wellbeing of the athletes. Specifically, it was deemed crucial to support the athletes' emotional wellbeing as this is the foundation for enhancing all other elements of the performance.

> (...) I have an opinion regarding how the athlete should be in an emotional sense and my way of working is aimed first at having the athlete emotionally well, which for me is the basis of everything.
>
> PT 2

3.1.4. Difficulties in the evaluation process

The PTs refer to the challenges experienced across different phases of their professional development. Four key barriers to carry out evaluations were highlighted, with the first being player culture (i.e., buy-in and adherence). To overcome this challenge, the PTs conduct educational sessions on the importance of evaluating performance for athletic development to influence perceptions and subsequent engagement.

> (...) the daily conversation, in the moments together of conversation when a trust begins to be produced and you begin to explain to him... he is going to be something in which you must have him at the maximum of the maxims of his will to carry them out, because if he did not have the will, it is preferable not to do anything because the data would not be valid.
>
> PT 7

Another element pointed out as a factor that hinders the application of the evaluations is the club's own culture and standards. This can relate to the lack of economical allocation of resources allocated for assessing physical performance. Most PTs reported not to having adequate equipment to conduct their role and often the PTs themselves have to source equipment or facilities to implement evaluations.

> (...) the resource, we did not have it in the club and I had to go out and look for it in clinics, sports centers that had a isokinetic device, but once it was achieved, when they gave me the values to evaluate each of the athletes, this It was escaping from the reality and possibilities of the club and from that point of view what I had to do was manage publicity to put in the stadium and lower the costs of the evaluation.
>
> PT 4

Finally, there are also some problems at the operational level of different origins such as the structure of local and international competitions that can affect the planning, the fatigue of the players at a general level (physical and mental), and the change of opinion of the head coaches without prior notice and environmental factors.

> (...) then there are other elements such as environmental ones, there must be optimal conditions to carry out the test, it is temperature, humidity, because they are things that influence the result.
>
> PT 7

3.1.5. Weekly distribution of physical abilities

Physical trainers consider that the structure of each microcycle should aim to improve all elements of performance, including technical, tactical, mental, emotional, and physical as part of a holistic model. PTs modify the structures of the drills that are undertaken by players by changing pitch/drill dimensions, number of players, durations, and goals depending on days within the weekly schedule (e.g., competition, day +1, day +2, day −4, day −3, day −2, day −1, and competition). Day +1 tends to be targeted toward promoting recovery (one day of active recovery and another day of passive recovery). Days −4 to −1 are days of optimization of elements of performance. In a microcycle with a mid-week match, more recovery days may be implemented within the schedule and fewer days may be allocated to performance optimization. Day +1 or +2 can be used for passive or active recovery, with PTs preferring active recovery on day +1 to speed up and facilitate the recovery process and passive recovery or rest on day +2. However, some head coaches prefer to carry out passive recovery on day +1 to promote psychological recovery after the competition and leave active recovery for day +2 being a training more intermittent and with a greater number of rest breaks that allow players to recover better before the following effort. In addition, the active recovery day can be used to balance the loads of the players who did not play or who played fewer minutes during the competition. At certain times, this can also be done after the competition on the field itself in a "cool down" format.

> (...) the second day (+2) is of active recovery and a differentiation is made between the players who played the entire game and those who played <45 min and did not play, must have a higher load.
>
> PT 1

On day-4, trainers focus on physical conditioning training with a reduced number of players (e.g., 1 vs. 1 or 2 vs. 2), which involves accelerations, decelerations, duels for the ball, jumps, and changes of direction, interspersed with periods of reduced effort. The PTs declared that given that some players may not be 100% physically or emotionally recovered, it may be necessary to control and manipulate the intensity for certain players. This can involve different strategies, such as reducing the number of drills a player performs or providing the player with lighter duties within the session.

> Strength work on day-4, there is a focus for tasks focused on accelerations and decelerations that cause explosive actions of short duration.
>
> PT 8

Day-3, being the furthest day from the previous and subsequent competition, tends to involve larger structures and more players. This allows the main behaviors in the different phases to be developed more collectively (offensive and defensive transition) and moments of the game (offensive and defensive organization). It is intended that the players cover similar distances and reach maximum speeds consistent with those reached in competition. Data analysis can be carried out after training sessions to determine those that have not reached the established parameters. It is necessary to point out that for this type of control, it is necessary to have GPS devices that provide feedback in real time.

> We call it the day of resistance, but at the base it is to create more specific contexts of everything that we want to work on in the game, therefore, resistance is not only aerobic resistance, it is a specific resistance, which later moments of the game will require us for the different positions (...) we try to achieve what is known as speed running that we achieve during the competition.
>
> PT 5

Day-2 is oriented to higher speed actions, which can be achieved in a specific way, but with low complexity in decision-making.

Finishing exercises with pursuit or more analytical linear running exercises of 30 m or more, with long recovery periods and reduced execution periods, are usually used.

> On a more speed basis, not only in analytical-type actions, but also with more specific finishing actions, arrivals to the area and faster actions with a short duration (time) but with enough recovery time between the different actions.
>
> PT 5

Day-1 is oriented to active recovery or match activation. This day together with the speed day is also recognized as tapering and less of a physical impetus. The day before the competition is also focused on completing match preparation, with tasks focused on reaction speed and covering more detailed elements of the competition from a psychological, technical, and tactical preparation.

> The last day, which is a little more focused on the socio-affective part, the work of some tactical concepts of stopped ball and in the activation, we make games that are more oriented in the union of the group and the creation of bonds between the players, to be able to go all united to compete with the rival on duty.
>
> PT 2

During the two match microcycles, recovery becomes much more of a focus when compared with one game week. The main emphasis of the week is to optimize performance, but it was also a key priority in managing physical elements that help maintain performance such as reducing fatigue, overreaching, and injuries. For this, PTs use different strategies that range from reducing the duration of exercises and training sessions to combining days off with different stimuli such as strength with resistance or speed with activation, or strategies focused on the methodology of the head coach.

> (...) at certain times you intend to recover, but it may be more important to adjust certain situations or certain technical-tactical behaviors than to have the players 100% recovered (...) the challenge for the head coach is planning and creating training, in order to obtain the greatest possible fruit, with the lowest cost.
>
> PT 7

3.2. Monitoring and control of training and competition

3.2.1. Use of monitoring instruments

Monitoring and control of training have become fundamental factors in soccer for maintaining high performance in matches and managing players' workloads (Figure 3). There was a revelation that the practitioners used monitoring methods that focused primarily on three factors, including subjectively assessing the player's wellbeing prior to each training session, monitoring GPS activity throughout the session for objectivity, and analyzing data post-session.

Before the session, *"the use of wellbeing questionnaires"* is implemented to minimize fatigue and injury risk and maximize a player's physical and emotional wellbeing.

> (...) we use the Wellness questionnaire, which allows us to know what conditions the athlete is in to carry out the training session.
>
> PT 1

During the session, "external load control" can be monitored in real time or after the training session on the premise that the club possesses "live" feedback systems. A consensus existed in the current study that practitioners used GPS devices, with the training session controlled by the quantification of specific parameters (i.e., total distance, accelerations, decelerations, maximum speed, and distances at high and very high intensity).

> GPS for external load, (...) I chose to take only some indicators (...) first the total distance, then (...) ranges of higher speeds that would be maximum and sub-maximum and then (...) accelerations and great accelerations and also finally the maximum speed reached.
>
> PT 7

"Internal load control" was determined by the subjective perception of effort (CR10 scale). For this process, the PTs recommend individualized protocols, which were applied 30 min after training so as not to reduce the influence of scoring associated with collecting data immediately after a session. Players were educated and familiarized with scales in advance of use to ensure accurate interpretations and valid data. The value of using heart rate as an important objective monitoring tool was recognized among the practitioners, but this metric is often omitted given the discomfort associated with wearing these devices on the front. Some PTs used blood markers such as CK to determine muscle damage, but it is generally used at times when more than one match per microcycle is completed. Blood lactate was not used for monitoring due to the complex application and the information deemed not necessary for the planning process.

> (...) post-training we applied the subjective effort perception scale, and there we had important data on how the player felt the training load.
>
> PT 2

3.2.2. Indicators used in monitoring and their influence on planning

The information collected from the training session is used to estimate load and determine whether the weekly load is within optimal parameters to promote adaptation and reduce overreaching. At the statistical level, the information is used to make comparisons between players and microcycles or between sessions and competitions and then to estimate metrics such as the Z-score to assess where the player is in relation to the team average and specific positional roles.

> (...) the metrics are organized according to the competition, (...) this allows us to evaluate more from the performance point of view.
>
> PT 6

At a collective level, monitoring allows a more general view of the total load of the session, competition, or microcycle, but the major adjustments are made to individuals. This may be attributed to the understanding that the specificity of playing positions requires stimuli and demands that vary. In this sense, the information is

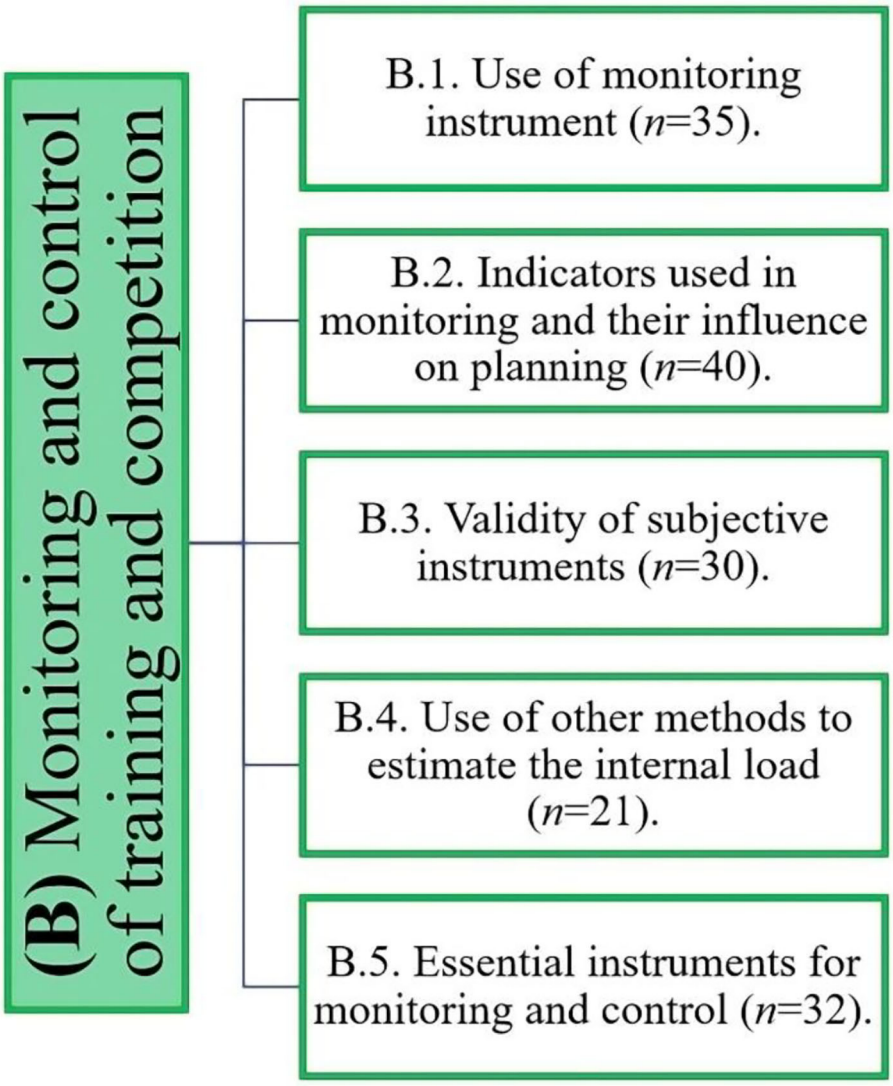

FIGURE 3
Distribution of the evidence obtained on the monitoring and control of training and competition.

analyzed to adjust the loads when the expected values are not reached or exceeded.

> (...) the individual data allowed us to know which athlete we had to raise or lower the load.
>
> PT 2

3.2.3. Validity of subjective instruments

Subjective evaluation instruments are recognized, used, and validated by all PTs on a daily basis; however, they make some recommendations in their application. For instance, the application of the questionnaire must be applied to a certain degree of privacy so as to reduce bias. The RPE should be taken and recorded approximately 30 min after the end of the session or competition. The subjective monitoring questionnaires should also be shortened where possible to increase engagement. The results that appear substantially different from the group average are questioned and addressed with the player in an effort to understand the nature of the response, given the complexity of collecting subjective data.

> The evaluation of the effort perception scale or any other tool that gives me the proximity to what is happening to the athlete is going to be crucial for me not to make a mistake and give the head coach a tired athlete at the time of the competition.
>
> PT 4

3.2.4. Use of other internal load indicators

In general, the trainers value and used heart rate monitors. However, all the trainers made the same comment related to the lack of comfort of the monitors/bands, interfering with player buy-in. CK was the most used blood markers to determine muscle damage, but it is generally used when there is more than one competition per week to try to help in the recovery process without creating overloads in the players and to reduce the invasion of drawing blood weekly.

> Yes, we already use the cardio frequency meter and we stopped using it because of the discomfort expressed by the players.
>
> PT 5
>
> We use the CK indicator as an indirect measure of muscle damage.
>
> PT 8

Other tools that PTs have used to monitor players and determine the degree of recovery range are sleep analysis with an electroencephalogram (EEG), hydration levels with a refractometer, and estimated neuromuscular capacity with a jumping platform.

> (...) strength is also a good indicator to determine fatigue and that is why we use jump ability as a method to evaluate 48 h after the game.
>
> PT 3

In this same sense, an indicator that is not used and to which PTs do not give importance is the measurement of lactate, which in their opinion is not practical to be applied in the normal training process.

> Lactate for me is not useful and impractical and I don't use it.
>
> PT 7

3.2.5. Fundamental elements for monitoring

The PTs highlighted that GPS devices are crucial to obtain this information ideally in real time to make decisions that allow them to quickly adjust loads.

> (...) the GPS would be to control the external load and have this possibility of controlling them at the moment.
>
> PT 2

At the internal load level, the use of the different subjective perception questionnaires is valued and validated and was applied before and after training sessions.

> (...) the Borg Scale, Wellness Questionnaire are simple things that I am already familiar with and use and have worked for me, because I believe that sometimes less is more.
>
> PT 2

In this same sense, the heart rate appears as a valid and objective indicator of effort at the internal level, for which its value is recognized and its use is recommended, as well as CK analysis to determine muscle damage.

> (...) heart rate, because it is an objective measure and is more valid, can be influenced by various factors, but during training, it is logically a valid indicator.
>
> PT 7

Other elements that PTs consider important for this process are the creation of multidisciplinary departments that allow players to be monitored in a more comprehensive way. They revealed that this should include nutritionists, physiologists, doctors, and coaching staff to thoroughly analyze the preparation strategies, training processes, and recovery regimes.

> (...) first a good monitoring center, (...) with a physiologist, physical trainer, a monitoring manager generating a competitive department... internal, debatable where all the variables are analyzed very thoroughly.
>
> PT 3

3.3. Injury prevention

3.3.1. Main causes of injury

The PTs highlighted three main elements that are considered most important to minimize injury risk, including, previous injury, age, and fatigue. Other less commonly highlighted factors were poor recovery, match congestion, contextual variables, and psychological factors (Figure 4).

> If an athlete has already had an injury, the probability of suffering another injury is very high, therefore, the care with that player must be doubled.
>
> PT 6

Physical trainers also consider other elements as risk factors for injury, such as low levels of oxygen consumption, high levels of body fat and low levels of muscle mass, returning to competition prematurely, methodological elements (absence of preventive work), dangerous training processes, poor diet and rest habits, muscle deficits, overload, and underload.

> Players with a low level of oxygen consumption are more likely to suffer an injury than a player with a good oxygen consumption.
>
> PT 1
>
> (...) deficits at the muscular level, it also seems to me something very relevant or something to which we give a lot of relevance... if a player has a lot of difference or significant differences between the lower limbs, it can be a sign that he will suffer an injury in a period next.
>
> PT 5

3.3.2. Use of prevention programs

Injury prevention programs used by PTs focus on those considered multicomponent, since they consider different elements, such as central strengthening (CORE), eccentric exercises, proprioceptive exercises, running technique work, speed, total-body resistance exercise (TRX), and FMS. However, some coaches prefer not to refer to these programs as preventive, but rather as optimization programs. This appears to be linked to their focus on improving the ability of the players, which will secondarily allow them to be better conditioned to the demands of the game.

> (...) we have multicomponent injury prevention programs, that is, that use those exercises that are described in the literature, such as the Nordic exercises, Copenhagen abduction, balance exercises, some FIFA 11+ exercises (...), using those exercises that have already been validated and that have some efficacy in preventing injuries and we do it that way.
>
> PT 8

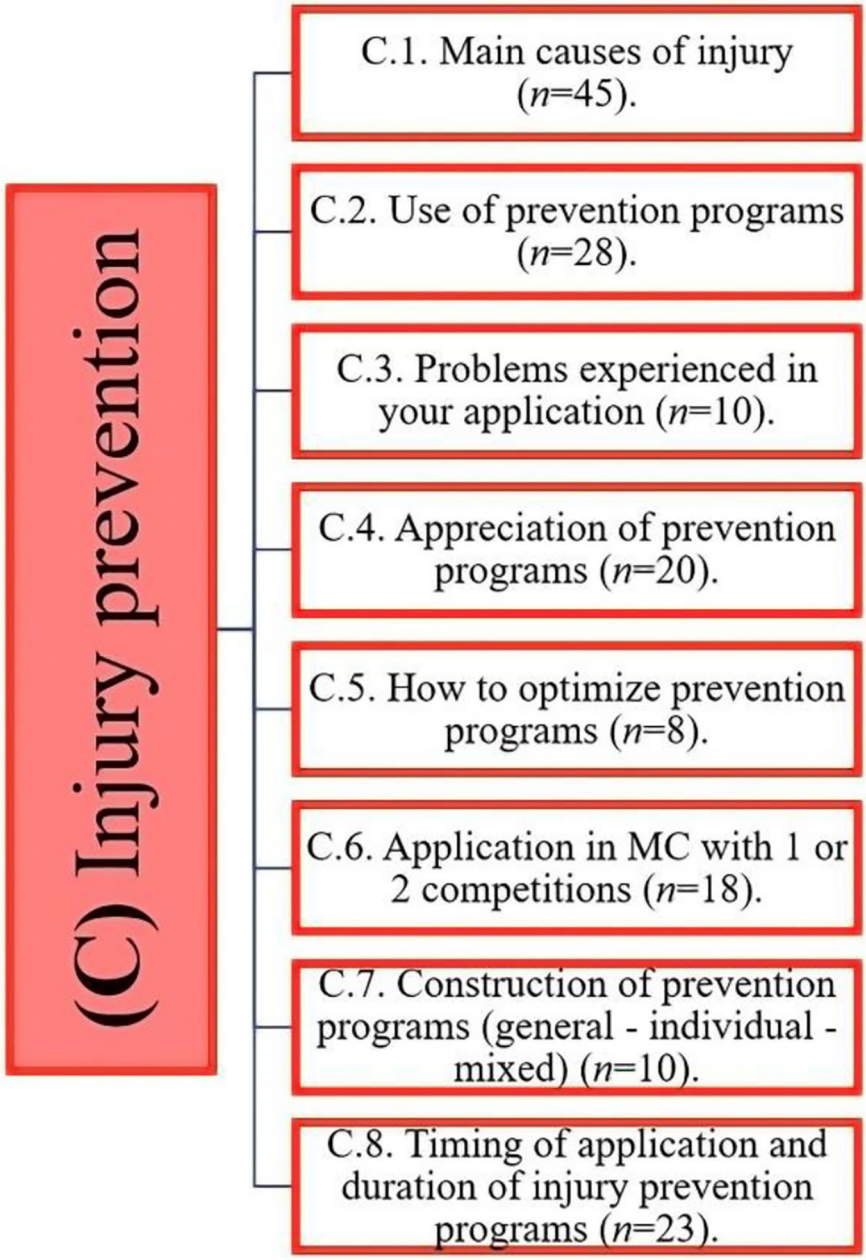

FIGURE 4
Distribution of the evidence obtained on injury prevention programs.

The PTs refer to other elements that they consider fundamental within the prevention process that are due to the training methodology used. The alternation of loads is completed from the day of active recovery (+2 or +1) and up to the activation session (−1).

> When training in a contextualized way, the muscle creates adaptations in specificity, that is, the muscle fiber adapts to the effort or stimulus that is required. This is essential.
>
> PT 1

3.3.3. Problems experienced by the physical trainer in the application of preventive programs

The participation of the players in a professional context does not seem to be subject to great difficulties since, due to contractual elements, the players must carry out the activities indicated by the technical staff who leads the sports project. For this reason, participation in prevention programs is high and absences are relatively low and motivated by specific reasons.

In contrast, they highlight the importance of accurately instructing players during their training process (e.g., young players) on the importance of these preventive works,

so that it becomes a self-care habit that lasts throughout their career.

> I haven't had any problems, I think that the different teams have been working well for a long time and the players, despite changing clubs, understand that before training they have to do some exercises that are important for their health.
>
> PT 2

However, the problems that some PTs have experienced are punctual, such as (1) assignment of the players in different work groups (headlines—reserves), which generates poor status in some reserves; (2) some young players who did not have good professional training related to injury prevention issues and, therefore, are not used to it; (3) minimal human resources to control and guide tasks; (4) refusal of some specific exercises; and (5) the sports context (team or selection).

> (...) there are specific exercises with which we later have more difficulties, specifically the Nordic hamstring exercises.
>
> PT 8

3.3.4. Appreciation of prevention programs

The assessment and acceptance of injury prevention programs by head coaches and the medical staff according to PTs are quite high. In the case of the head coach, having all the players available and in optimal conditions is essential to achieve the sporting objectives. However, PTs recognize that depending on the professional training and the head coach's own experience as a player, sometimes they generate some difficulty, so it is essential to justify and explain the relevance of this process. In contrast, the medical departments are key in this process, since their contribution, experience, and knowledge of the players who have been with the club for a longer time help to better optimize the process. In this sense, there is agreement that the implementation of prevention programs should be designed by a multidisciplinary team considering the maximum amount of information from athletes for greater optimization and effectiveness.

> (...) with the medical team this is done in direct collaboration and many times we adjust the training programs because they are carried out on a daily basis (...) we adjust in relation to the complaints or problems that there are from the players in the medical department, to clinical level… for this reason there is a 100% interaction with the medical department.
>
> PT 8

3.3.5. How to optimize prevention programs

There is agreement that injury prevention programs can be optimized to obtain the maximum benefit from their application, whether from a prevention-oriented perspective or the improvement of the athlete's physical capacity. PTs use various strategies such as (i) ensuring the work is soccer-specific and simulates the movement patterns performed during a match; (ii) design programs that are carefully implemented to determine a balance with workload, fatigue, rest, and nutrition; (iii) consider all risk factors, both internal and external; (iv) create harmonious, dynamic, and engaging programs that facilitate their application; (v) elements of the medical department such as kinesiologists or physiotherapists should be incorporated to have a more proactive role in injury prevention; (vi) train and educate academy players on the importance of prevention programs to adhere to such protocols as they progress to the professional level; and (vii) individualize the prevention programs for each player, attending to their needs and abilities.

> (...) Preventive work must be related to the main tasks (specific field work), since preventive tasks are complementary to the main tasks and must have a certain link with the type of muscle contraction that is applied.
>
> PT 1

3.3.6. Application in microcycle with 1 or 2 competitions

The application of prevention programs is mainly based on whether teams compete in a one- or two-game microcycle, with PTs adjusting loads accordingly. Thus, a maintenance injury prevention program is carried out on one match microcycles, but not on a two-game weekly schedule to avoid negatively influencing player wellbeing.

> By having a standard microcycle with competition from Sunday to Sunday, the application of prevention programs is normal, considering the different elements that were mentioned above depending on the day of the week.
>
> PT 1

To reduce load, alterations are made to compensate for the additional game in a competitive microcycle with two matches per week. These measures are used in order to promote physical recovery for the next competitive encounter, allowing the player to focus on the more technical and tactical aspects of the next game.

> There is a substantial reduction in the volume of the load of these prevention programs in the gym. Many times they stop carrying out these programs in congested periods of the sports or competitive calendar... this manifests itself with a reduction or a complete absence on certain days of these programs.
>
> PT 8

3.3.7. Construction of injury prevention programs

Physical trainers consider two major aspects when constructing prevention programs. The first relates to elements of the PTs' own learning and their scientific knowledge on this subject, which is used in a broader and more general context. The second adds individual factors to these elements, such as injury history, and anthropometric or physical evaluation results to determine imbalances that may affect the player's health. Consequently, the trainers, when considering both elements, consider that the construction of their prevention programs is of a mixed nature, since they articulate both elements when constructing these programs.

> We did general days in which the work for the entire team related to strength and they also had individual work guidelines for each one, based on the body composition evaluations, the

> FMS evaluation, the injury questionnaire and your previous injuries, to strengthen your irrigation areas.
>
> PT 2

3.3.8. Timing of application and duration of injury prevention programs

The moment of application of the prevention programs is mainly oriented to be carried out prior to the main training session, mainly when the work is oriented toward the lower limbs to activate and prepare the neuromuscular system for an intense session. Another factor is related to the willingness of players to work before the field session and not after. However, there is also the possibility that these programs are carried out after the main training session when double shifts are carried out or when the muscles need to be worked to correspond to the upper limbs.

> (...) the player in general prefers to arrive earlier and do this work before, instead of doing more work after the training session.
>
> PT 5

The estimated duration of the prevention work can fluctuate between 10 and 35 min, depending on the day of the week in which it is being carried out. Another factor that influences the duration of the prevention program relates to the player who is carrying out the session and the context involved with whether the player required greater work or whether recovery is a higher priority.

> It depends on the type of work it is, it can last 10, 15, or 20 min depending on the work that is done.
>
> PT 6

4. Discussion

The aim of this study was to investigate the contemporary practices of professional soccer PTs across two continents. This study provides an understanding of the contemporary practices of PTs from two continents and different leagues. The PTs presented an extensive period of experience at a professional level and were educated to a high academic level. This provides an understanding of how these PTs implement the theory acquired in their training process into practice and how they adjust according to their experience in the professional context in three areas (Figure 5).

4.1. Anthropometric evaluation

The anthropometric and body composition assessments are considered an important indicator of fitness for PTs. This was considered an important aspect of physical fitness for soccer by the current participants, since the superfluous adipose tissue can act as dead weight in activities in which body mass is repeatedly raised against gravity when running or jumping during play (Reilly, 1994). In addition, possessing favorable body composition (high muscle mass and low-fat indices) has been considered an important selective factor to achieving success in sports (Rienzi et al., 2000). However, caution is advised when interpreting such claims, as each successful athlete may possess different physical characteristics (Rienzi et al., 2000). Therefore, each PT assigned less importance to this matter, assuming that other physical performance parameters were adequate. Practitioners used skinfold assessments for assessing body composition. Skinfolds, although less reputable than other more sophisticated methods (e.g., DEXA), have been advocated for their simplicity and day-to-day consistency (Kasper et al., 2021). Minimal information was provided on how the practitioners might use the data obtained to determine subsequent nutritional and training protocols. Therefore, more studies appear to be warranted to determine how skinfold data are used to inform practice and delve into the specific role of the PT in relation to skinfold practices to enhance the understanding of this key undertaking within the applied setting.

4.2. Physical evaluation

To cope with the physical demands of soccer, players must be able to adapt to unpredictable changes and unorthodox movement patterns (Drust et al., 2007), which increase energy expenditure over anticipated locomotion patterns (Reilly and Bowen, 1984). Such movements can include acceleration and braking, forward, backward, or sideways actions, and cutting and side-stepping maneuvers to evade the opponent's defensive marking (Drust et al., 2007). The use of physical fitness tests helps to examine the abilities of soccer players (strength, power, speed, agility, and aerobic and anaerobic capacity) and training programs to be better targeted. This is even more crucial given the complex nature of soccer (Svensson and Drust, 2005). The evaluations can be applied both in the laboratory context, which is usually more expensive and sensitive, and in the field, which is carried out by the trainers themselves at a lower cost (Drust et al., 2007). The evaluations of the physical capacities of the players were highly supported and used by the PTs to provide a more comprehensive depiction of player fatigue and whether recovery should be prioritized akin to previous research (Viru and Viru, 2001). This careful monitoring allows practitioners to demonstrate the evolution of the training process and information to make more accurate decisions about training prescription (Svensson and Drust, 2005). Such evaluations provide a logical framework for the use of performance tests that better understand the physiological demands of soccer (Drust et al., 2007). The PTs' interviews revealed that there is also a classification by positions for a more accurate and specific analysis of the demands of competition, as suggested within the literature (Rienzi et al., 2000; Barrera et al., 2021). In this sense, and despite the difficulties that the participants may experience during the evaluation process (instrument, logistics, cultural, among others), they continue to be used to try to understand the player's performance capabilities. The practitioners tended to favor field-based tests that are more sport-specific, given their acyclic nature that is not amenable to time-series analysis and is incompatible with traditional exercise study models in laboratory conditions (Svensson and Drust, 2005).

A key laboratory test that was commonly used among practitioners, provided that the necessary resources were available for this purpose, was isokinetic dynamometry evaluations of the lower limbs to determine peak torque and muscle imbalances (strength), specifically around the main knee extensor and flexor muscles (quadriceps and hamstrings) (Duarte et al., 2018a,b; Rosa et al.,

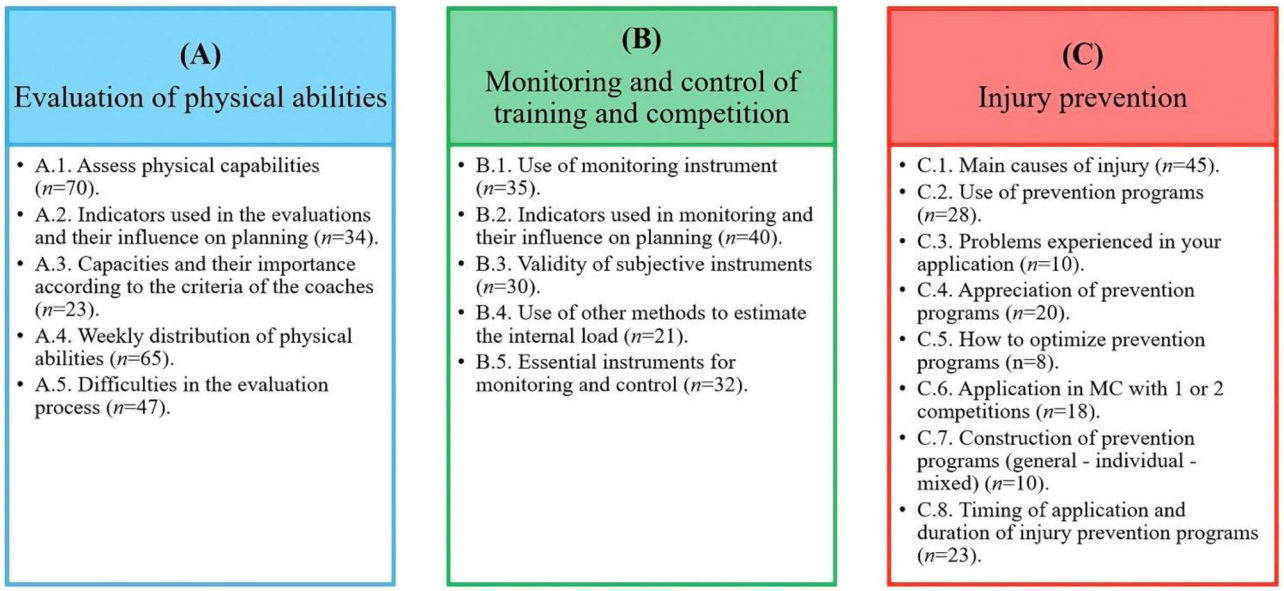

FIGURE 5
Summary of the findings found in the three areas studied **(A)** Evaluation of physical abilities; **(B)** Monitoring and control of training and competition; and **(C)** Injury prevention.

2022). Evaluation of adductors and abductors with a dynamometer (Smart Groin Trainer) to identify imbalances or muscle weakness and monitor the progression of optimization and rehabilitations (Rosa et al., 2022) and neuromuscular capacity assessments *via* CMJs and SJs were also performed (Jovanovic et al., 2011; Loturco et al., 2018; Boraczynski et al., 2020; Rosa et al., 2022). The field-based tests carried out focused on speed over numerous distances (5, 10, 20, or 30 m), agility (Illinois T), and aerobic capacity (Yo-Yo test), which have been widely used in the scientific literature (Little and Williams, 2005; Mirkov et al., 2008; Kaplan et al., 2009; Jovanovic et al., 2011). This shows consistency between the practices employed and the scientific evidence base. When asked about the importance of specific physical abilities over others, the vast majority highlighted strength as the key fitness component, since matches incorporate explosive efforts such as sprints, jumps, tackles, kicks, changes of pace, and duels for ball possession (Cometti et al., 2001) to ensure successful performance in competition (Papaevangelou et al., 2012). Therefore, the ability to generate explosive muscular force in as short a time frame as possible is an important determinant of performance (Thorlund et al., 2009). However, some PTs also highlighted the relevance of aerobic capacity as an important element to ensure players can tolerate fatigue and recover more quickly (López-Revelo and Cuaspa-Burgos, 2018), as well as its benefits as a moderating factor of injuries (Malone et al., 2017a; Windt et al., 2017). These revelations are plausible, as both abilities are considered important determinants of soccer performance, as they are key characteristics of physical ability and the main regulators of important soccer-specific tasks (Hoff and Helgerud, 2004). The PTs interviewed revealed the importance of evaluating physical abilities from both a performance and injury prevention and rehabilitation perspective to support decision-making in the return to competition. It is recommended that the optimization process focuses on strength and aerobic capacities that, for the PTs, appears to be more predominantly targeted toward achieving sporting success.

4.3. Monitoring and control of training and competition

In the world of sports, the main objective of athletes and coaches is to achieve success in competition. However, by increasing the frequency, duration, or intensity of training, they risk creating excessive fatigue that can lead to functional impairment, described as "overtraining syndrome", "staleness", or "burnout" (Hooper et al., 1995). Therefore, it is essential that PT permanently monitors and controls the training process, since this process helps establish a balance between performance and recovery (Gaudino et al., 2015a; Moalla et al., 2016). This method also allows control over weekly workloads, which enhances physical conditioning and prevents injuries or illnesses (Jaspers et al., 2017). However, achieving these goals requires careful planning and manipulation of the training load over the course of a competition schedule (Gabbett, 2016).

All PTs noted that GPS devices are key to the monitoring process, consistent with the literature and reported use in Europe, the United States, and Australia (Akenhead and Nassis, 2016). Reasons given for the use of such units were the attainment of valid data (Reinhardt et al., 2019), data are reliable and relevant to track external load in professional soccer, both collectively and individually (Rave et al., 2020), and the device allows the measurement of positions, speeds, and movement patterns of the players (Cummins et al., 2013). Differentiation of the specific loads is recommended according to the individual demands of the game or position (Barrera et al., 2021); the evidence is supported and shared by PTs.

It was also highlighted that the practitioners use subjective tools, which allows them to understand how the player is reacting to certain external loads and also obtain information on the training performance that can be expected from individual players during a training session (Malone et al., 2018), during different days and weeks, and also at different times of the season (Nobari et al., 2021). For this process, the PTs mainly use two subjective

perception questionnaires. The first is the wellness questionnaire that provides information about the athlete before the training session and competition and the level of fatigue experienced (Cullen et al., 2021). It is important to note that the PTs recommend adopting or eliminating some questions according to their personal criteria (subjectively), so as to lessen the time burden of irrelevant questions. Second, the Subjective Perception Scale (session-RPE) proposed by Foster et al. (Foster et al., 1995, 1996, 2001; Foster, 1998) is used post-training and competition to quantify the load of the session at an acute level. This is considered a good indicator of the global internal load of soccer training (Impellizzeri et al., 2004; Casamichana et al., 2013; Fanchini et al., 2017), using the category proportion scale (CR10 scale) (Borg et al., 1987) for its duration. It was also revealed that educating players about the importance of this information for the process of planning and executing training is key to ensuring engagement. For this to occur, the PTs indicated that this information is not used to determine starting, substitutions, or non-squad players in the subsequent match, but instead the veracity of the information is important for an adequate optimization and care process.

The PTs stated that they do not use the acute-chronic load relationship for training control. A practice that we believe should be incorporated, since it has been shown that high chronic workloads can be useful as a control parameter for injury prevention when adequately achieved in professional athletes of all sports, such as rugby players (Hulin et al., 2016), Gaelic footballers (Malone et al., 2017b), and soccer players (Malone et al., 2017a), which can be a fundamental tool to incorporate into practice. The PTs also considered the use of heart rate important to estimate the internal load in a more precise and objective way and to plan training sessions, in addition to being an individual indicator of the assimilation of accumulated workloads (Naranjo et al., 2015). However, it was reported that the players feel discomfort when using the elastic bands on their chest, since it is necessary to adjust them constantly, in turn, making their application difficult throughout the season. This perhaps offers an avenue for future research with technology companies adjusting the products to ensure player comfort.

Some PTs who possessed the resources used CK as an indirect blood marker of muscle damage and overload in soccer players (Lazarim et al., 2009b; Thorpe and Sunderland, 2012), in conjunction with other measures (e.g., CR10 and wellness). This marker was typically used within two-game microcycles. However, contrary to anecdotal belief, PTs indicate that they do not use blood lactate due to the perception that this marker is impractical, and the information provided is not considered relevant for daily training planning and prescription. Coutts et al. (2009) pointed out that lactate alone cannot accurately explain the overall intensity of soccer exercises, but that the subjective perception of the players' effort, which is a simple, cheap, and easy-to-use tool, should be used as a more accurate indication. Finally, it should be mentioned that all this information is considered in the training planning process, both individually and collectively. It was also shown that wellbeing values far from the mean, as well as workload peaks, will force modifications within the training process, individually or collectively, since players respond differently to the same training stimuli (Mäestu et al., 2005).

In general, it must be understood that the use of technological tools for the estimation of the internal and external load has become essential in high performance. However, in the absence of economic resources, other options such as subjective questionnaires can be used to replace the indicators of internal load or recovery. In contrast, if the resources exist and it is intended to provide greater comfort to the athlete, there may be other options for monitoring the external load (i.e., camera-based systems). It is important that monitoring and control must be present in the training process, since they directly impact the planning of each session, whether microcycle or mesocycle, if the intention is to reach the maximum sporting level with the lowest possible risk of injury to players.

4.4. Injury prevention

Injury etiology models have evolved over the last few decades, highlighting a number of factors that contribute to the causal mechanisms of sports injuries (Windt and Gabbett, 2017). Three factors are highlighted: (1) internal modifiable and nonmodifiable risk factors (e.g., age and neuromuscular control); (2) exposure to external risk factors (e.g., playing surface and equipment); and (3) inciting events, in which biomechanical breakdown and injury occur (Meeuwisse, 1994; Meeuwisse et al., 2007). In this context, the PTs indicated intrinsic risk factors, i.e., the history of injuries and the age of the players, and extrinsic risk factors, i.e., the fatigue caused by training and the high congestion of matches (Dvorak et al., 2016). However, it should be noted that the PTs highlighted the complexity of the injuries and their unpredictability, which makes them a complex problem to predict and address.

As a product of the high complexity of injuries and how important it is to maintain low injury rates for sporting success, as well as for the economic sustainability of the club (Ekstrand, 2016), the PTs pointed out that they use multicomponent programs, which incorporate different exercises for different types of injuries that a player can suffer. It was also stated that these programs build on the basis of scientific evidence focusing on two topics: (1) main injuries that occur in soccer (e.g., groin injuries, joint injuries, and muscle injuries) (Chomiak et al., 2016) and (2) greater prevention benefits in these injuries, such as the Copenhagen Adduction exercise programs (Harøy et al., 2019), Nordic hamstring exercises (Al Attar et al., 2017a), reverse Nordic hamstring exercises (Alonso-Fernandez et al., 2018), knee-specific training modules (Krutsch et al., 2020), as well as the training methodology focused mainly on meeting the specific needs of the sports (e.g., accelerations, decelerations, distance covered at high intensity, and sprints performed, among others). The PTs indicated that the participation of the players in these programs is high, which eliminates the problems or difficulties that may arise due to low adherence (Engebretsen et al., 2008). These programs are carried out mainly before the training session, despite the fact that evidence has shown greater benefits against new injuries when applying for prevention programs before and after the training session (Al Attar et al., 2017b) and have a duration between 15 and 30 min. However, the duration times according to the literature do not influence the positive results of application in preventative programs for injuries suffered in the lower limbs, the type, severity, or mechanism of the injury (Rahlf and Zech, 2020). The configuration of injury prevention programs can vary depending on the day of their application within a normal microcycle (one competition) as well as in a microcycle with two competitions per week. Programs can often be overlooked during the fixture-congested periods of matches depending on the PT, and these variations have been shown to affect the effectiveness of programs (Van Beijsterveldt et al., 2013). These programs are designed in a specific way depending on the needs of

each player and the demands of the different structures (Alcalá et al., 2020), which has shown favorable results against muscle injuries and days of absence without recurrence (Melegati et al., 2013). Therefore, it is essential to consider the flexibility of the planning and delivery of these programs in order to achieve the benefits of these injury prevention programs.

The PTs believed that both head coaches and members of the medical team value the work done when using these prevention programs and highlight the importance of having a more interdisciplinary approach that involves different members in the optimizing process to reduce the risks related to the sports discipline given its high complexity, as suggested by the scientific evidence (Dvorak et al., 2016). Finally, the interviewed PTs believe that prevention programs can address the more specific demands of soccer, as proposed by Moras (Moras, 2000; Seirul-lo, 2017), with the degrees of approximation of the tasks in the auxiliary work.

Finally, PTs generally support the use of prevention programs, basing their decision on the available scientific evidence. However, they believe that improvements can still be made in these processes, which contribute to the prevention of injuries.

5. Conclusion

This study explored the contemporary practices of PTs in professional soccer across two continents. The data suggest that the evaluation of physical capacities is based on scientific evidence and different methodologies depending on the stage of the season (pre-season, competitive period, or end of the season). It became apparent that for some stages of the season, emphasis was placed on the development and optimization of physical qualities, while optimizing recovery and fatigue management was prioritized in other stages of the season. In contrast, the PTs monitored and managed the training load, supported the use of technological tools (e.g., GPS devices), and considered this aspect a fundamental part of the role. However, they also supported the use of subjective questionnaires, since some players deviated from the team average and, as such, required bespoke intervention. Finally, the PTs recognize the use of injury prevention programs, which are multi-faceted in nature, and require the support of several disciplines working in sync. However, there was a revelation that since contextual factors can influence the adherence to strictly working within the scientific guidelines, practice must change to encourage player engagement. Therefore, although the scientific guidelines are closely followed, some flexibility is shown within the role to accommodate a multitude of contextual factors. For current and future PTs who want to enter the sports discipline, this study will be a reference of what is done in high performance and the nuances that can appear in different situations during a season.

6. Limitations of the study and possible future studies

The main limitations of this research arise when considering a small number of participants. In contrast, it is possible that future investigations of this type replicate this interview in other contexts, compare, deepen, or adapt certain criteria that increase the knowledge of the practices of PTs in soccer or other sports disciplines.

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 human participants were reviewed and approved by Scientific Council and the Ethics Committee of the University of Coimbra (CE/FCDEF-UC/00692021). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JB-D, AJF, and HS: project direction, established the protocol, wrote and revised the original manuscript, and final approval for publication. AF: data analysis, critical revision, and final approval for publication. BF, SQ, JS, JR, IP, PC, HT, and AS: delivery of evidence of their professional work, critical and exhaustive review of the writing of the study in general, and final approval for publication. All authors contributed to the article and approved the submitted version.

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Conflict of interest

JR was employed by company Sporting Clube de Braga SAD. IP was employed by company Athletic Club Barnechea. PC was employed by company San Luis de Quillota. HT was employed by company Club de Deportes Antofagasta.

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1101958/full#supplementary-material

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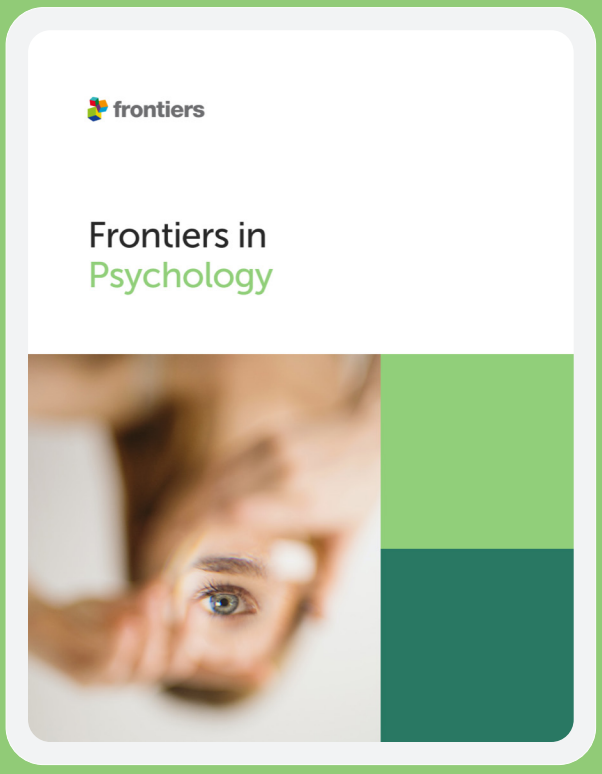

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