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Multidisciplinary perspectives on team sports: contextualizing training and competition demands

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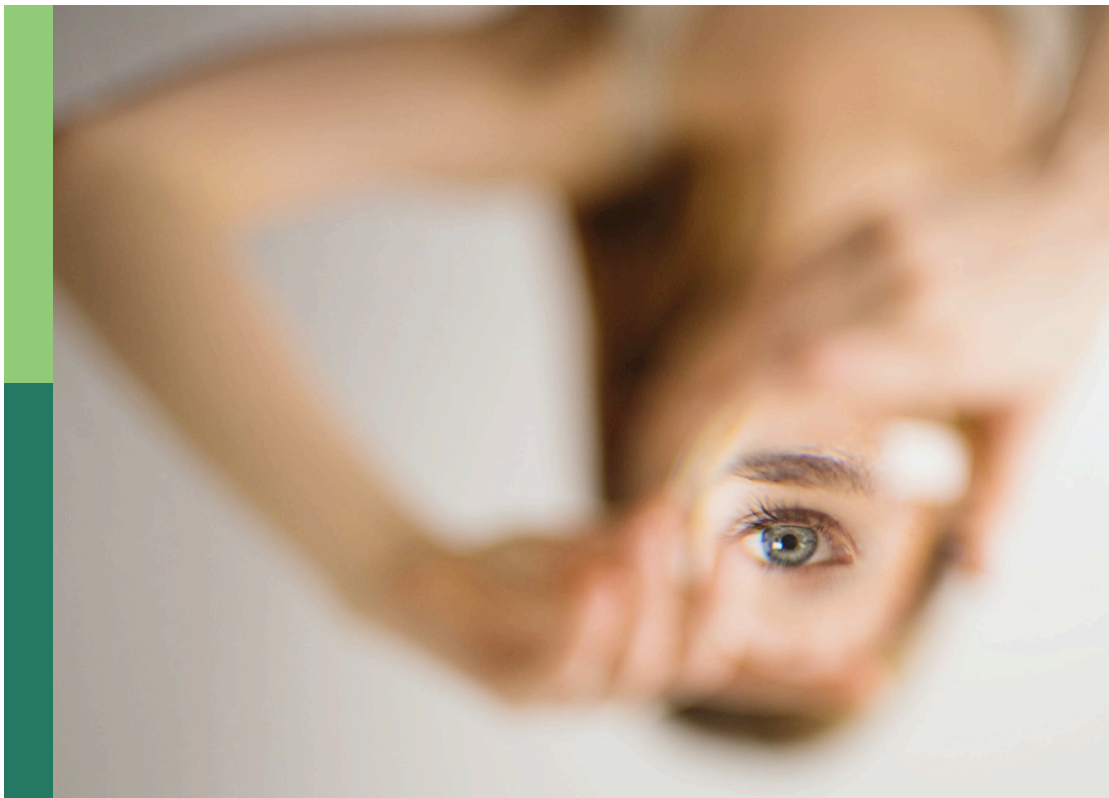

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Multidisciplinary perspectives on team sports: contextualizing training and competition demands

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Table of contents

04 Editorial: Multidisciplinary perspectives on team sports: contextualizing training and competition demands
Pierpaolo Sansone, Vincenzo Rago and Miguel-Angel Gomez-Ruano

06 Acute physiological, perceived exertion and enjoyment responses during a 4-week basketball training: a small-sided game vs. high-intensity interval training
Jinshu Zeng, Haris Pojskic, Jing Xu, Yuanhong Xu and Fei Xu

15 Association of self-efficacy and mental toughness with sport performance in Brazilian futsal athletes
Paulo Vitor Suto Aizava, Renan Codonhato and Lenamar Fiorese

23 Modeling the influence of basketball players' offense roles on team performance
Ruobing Chen, Mingxin Zhang and Xiao Xu

35 Impact of the number of players on the emergence of creative movements in small-sided soccer games: a systematic review emphasizing deliberate practice
Lucas Shoiti Carvalho Ueda, Michel Milistetd, Gibson Moreira Praça, Gabriel Silveira Guedes da Maia, Juliano Fernandes da Silva and Paulo Henrique Borges

51 Children can rate perceived effort but do not follow intensity instructions during soccer training
Marco Reinke and Gerd Schmitz

61 Effect of changes in the net height, court size, and serve limitations on technical-tactical, physical, and psychological aspects of U-14 female volleyball matches
Jose M. Palao, Aurelio Ureña, Maria P. Moreno and Enrique Ortega-Toro

72 Analyzing the impact of team-building interventions on team cohesion in sports teams: a meta-analysis study
Sang Hyun Kwon

81 Position and ranking influence in padel: somatic anxiety and self-confidence increase in competition for left-side and higher-ranked players when compared to pressure training
Rafael Conde-Ripoll, Adrián Escudero-Tena and Álvaro Bustamante-Sánchez

88 Investigating the effect of grit trait on performance and success in Hungarian athlete's sample
Annamária Apró, Nikoletta Fejes, Szabolcs A. Bandi and Róbert Járai

104 The influence of "momentum" on the game outcome while controlling for game types in basketball
Mingjia Qiu, Shaoliang Zhang, Qing Yi, Changjing Zhou and Mingxin Zhang

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Editorial: Multidisciplinary perspectives on team sports: contextualizing training and competition demands

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complex system (CS), situational variables, physical demands, athletic performance, physiological responses, technical-tactical analysis, perceptual measures

Editorial on the Research Topic
Multidisciplinary perspectives on team sports: contextualizing training and competition demands

Introduction

Team sports training and match-play require athletes to bring a mix of abilities to the table. They need to be physically strong and conditioned, tactically aware, technically skilled, mentally tough and socially intelligent. These abilities work together in a complex, interconnected way, affecting each other. Team sports research focuses on understanding what is needed in a game so that coaches and other performance support staff can assist athletes in developing the right skills and capacities. Given how complex team sports are, it's important to consider various factors from different areas—physical, tactical, and psychological among others—when analyzing performance.

Game-based conditioning

One of the most stimulating and useful training methods in team sport is game-based conditioning, because it places athletes in scenarios that closely resemble competition from multitude perspectives (i.e. physical, technical-tactical, psychological and cognitive). It is therefore not surprising that three articles published in this topic focus on game-based conditioning, and specifically small-sided games (SSGs). As found by Zeng et al. basketball SSGs elicited similar physiological (heart rate) and perceptual responses (rating of perceived exertion) than high-intensity interval training (HIIT) across a 4-week intervention while it was enjoyed substantially more than HIIT by female athletes. These findings indicate that basketball practitioners can be confident in incorporating SSGs to players' adherence and motivation in training. Additionally, Palao et al. manipulated the rules related to net height, serve and court size in under-14 female volleyball tournaments,

observing differences in technical-tactical variables (i.e. serves, attacks, blocks) of the game development according to specific constraints, while no differences were found for the physical demands (i.e. external load). Furthermore, Ueda et al. conducted a systematic review about how the number of players affects creativity in soccer SSGs training. The authors found that reducing the number of players and the court size facilitates exploratory behavior, variability and creative actions, which should be considered by soccer practitioners to implement these essential players' abilities.

Psychological aspects in team sports

Five studies addressed psychological aspects of team sport performance. A meta-analysis by Kwon quantified the effectiveness of team building interventions on team cohesion and found greater effectiveness for participants aged 15–20 years old competing at collegiate level, and engaged in interventions longer than 2 weeks. An interesting paper by Aizava et al. demonstrated significant relationships between self-efficacy and mental toughness with sport-specific performance outcomes such as wins, red cards and wrong passes. These novel findings on the relationship between psychological characteristics and technical-tactical aspects further strengthen the need for multidisciplinary approaches as suggested by this Research Topic. The study by Aprò et al. validated a questionnaire on grit traits in a sample of Hungarian athletes and found that national team athletes had higher grit scores, suggesting that this personality trait should be considered for talent identification and athlete selection. Reinke and Schmitz found that both children and pre-adolescents were able to rate their perceived effort during soccer training, with better abilities in 13-years old than 11-years old players due to their higher cognitive abilities thanks to their higher cognitive development, which suggests the relationships between cognitive and perceptual aspects of team sport performance. In padel players, Conde-Ripoll et al. found heightened self-confidence before competitive matches than training for both higher and lower-level players, while somatic anxiety was higher before competition than training only for higher-level players. The authors suggest that self-confidence and somatic anxiety should be monitored in padel practitioners, and a sport psychologist might help improve the players' mental skills to optimize their preparedness for the mentally demanding competitive matches.

Contextual and positional factors influencing basketball game performance

Two studies evaluated team and players' performances in the Chinese Basketball Association (CBA). Qiu et al. evaluated momentum, an important constraint that can significantly impact the game outcome in basketball. The study found higher occurrences of momentum for winning teams compared to losing ones; additionally, the game quarter is an important game part on which teams should perform well, especially for weaker team facing stronger teams. Chen et al. focused on the individual player and their impact on team offensive performances. The study described 14 offensive roles for native players and five for foreign players, with the performances of spot-up wings who attack and bigs who cut to the rim which significantly influence team's performance. These two basketball studies provide valuable information for coaches on how to design the team's tactical strategy by manipulating efforts across the game duration as well as players' roles.

Conclusions

Altogether, the studies published in this Research Topic have successfully covered relevant multidimensional aspects of team sport performance. These findings related to game-based conditioning, psychological traits and game-related contextual and positional factors have been demonstrated to significantly impact players' and team performances and should therefore be well considered by team sport coaches as they can increase the team's chances of success. Specifically, (1) SSGs can be implemented to increase players' enjoyment, creativity, and to manipulate their physical demands; (2) team cohesion, self-efficacy, self-confidence, mental toughness and anxiety should be well considered by team sport coaches as these psychological traits are associated with success in competition; and (3) in the CBA basketball league, generating momentum and improving performances of wings and centers can increase the chances of success. Overall, the studies in this Research Topic have explored several important factors that influence how teams and players perform. Coaches should take these insights into account to improve training, helping their teams perform better and increase their chances of winning.

Author contributions

PS: Conceptualization, Writing – original draft, Writing – review & editing. VR: Conceptualization, Writing – review & editing. M-AG-R: Conceptualization, Writing – review & editing.

Conflict of interest

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

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Acute physiological, perceived exertion and enjoyment responses during a 4-week basketball training: a small-sided game vs. high-intensity interval training

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Introduction: Although previous research found that small-sided game (SSG) training was more enjoyable than high-intensity interval training (HIT) in various sports, no data were provided during longer training period in basketball. Furthermore, the comparison of internal loads between the two training approaches needs to be further examined. Thus, this study aimed to examine the acute physiological, perceived exertion and enjoyment responses during 4-week progressive basketball SSG or HIT programs.

Methods: Nineteen female collegiate basketball players were randomly assigned to two groups that performed either HIT (n =10) or SSG (n =9) 3 times per week for 4 continuous weeks. Average and percentage of maximal heart rate (HR_{mean} and $\%HR_{max}$), rating of perceived exertion (RPE), and physical activity enjoyment (PACES) were determined during each training session.

Results: There was a main group effect in PACES (p <0.001; η_p^2 =0.44, moderate), and SSG had higher PACES than HIT in each week (p<0.05). There were no significant interactions or main group effects in HR_{mean}, $\%HR_{max}$ or RPE, but a main time effect was found in HR_{mean} (p =0.004; η_p^2 =0.16, minimum), $\%HR_{max}$ (p <0.001; η_p^2 =0.25, minimum), and RPE (p <0.001; η_p^2 =0.31, moderate), respectively. In the SSG group, although no significant differences were found in HR responses, $\%HR_{max}$ was below 90% in week 1 and week 2. Accompanied with changes in $\%HR_{max}$, RPE in week 1 and week 2 was lower than that in week 3 and week 4 (p<0.05).

Conclusion: Our findings suggest that SSG and HIT elicit similar acute HR response and RPE level, but SSG is perceived as more enjoyable and therefore it is more likely to increase exercise motivation and adherence comparing to HIT. Moreover, it seems that half-court, 2 vs. 2 SS Gtraining format with modified rules and lasting ≥7.5min should be prescribed as an enjoyable training alternative to provide optimal cardiovascular stimuli (>90% of HR_{max}) for female basketball players.

KEYWORDS

internal load, training evaluation, exercise adherence, training periodization, women players, self-determination theory

1. Introduction

Basketball is an intermittent, court-based team sport characterized by high aerobic and anaerobic demands, frequent changes of movement and various technical-tactical scenarios (Stojanovic et al., 2018). Data from game activities indicate the predominant utilization of

aerobic metabolism (Ben Abdelkrim et al., 2010; Latzel et al., 2018). Aerobic capacity contributes to the repetition of high-intensity movements, as well as the ability to maintain high quality of these movements with limited recovery time (Ben Abdelkrim et al., 2010; Dupont et al., 2010).

For effectively improving aerobic capacity, training at high heart rate (HR) zones (above 90% of HR_{max}) is considered to be more effective than lower HR zones training (Delextrat and Kraiem, 2013; Malone et al., 2019). In this regard, high-intensity interval training (HIT) and small-sided game (SSG) have been widely used to improve aerobic fitness in basketball players because these training approaches can elicit cardiovascular response above 90% of HR_{max} (Delextrat and Martinez, 2014; Zeng et al., 2022). SSG includes a series of shorter-duration games with smaller numbers of players and modified rules compared to real matches (Clemente, 2016), and HIT includes a series of brief intermittent workouts (e.g., sprints) performed at a maximum or near-maximal effort (Gibala and McGee, 2008). Moreover, to achieve optimal effects during a training period lasting several weeks or months, training load (i.e., durations, frequencies and intensities) should be gradually increased in response to advanced training-induced adaptations (Smith, 2003; Triplett and Chandler, 2017). With this in mind, progressive SSG and HIT training programs are frequently applied and compared in previous studies (Delextrat and Martinez, 2014; Zeng et al., 2022). For instance (Delextrat and Martinez, 2014) showed that both SSG and HIT interventions performed twice per week for 6 weeks significantly improved aerobic capacity in junior male basketball players. Moreover, a shorter SSG and HIT training period (i.e., 4 weeks) with a higher training frequency (i.e., 3 times per week) showed to be effective in enhancing aerobic capacity in female basketball players (Zeng et al., 2022).

However, although the aforementioned studies evaluated outcomes of interventions (pre- vs. post-intervention), a lack of data detailing physiological and psychological responses limits the ability to comprehensively assess program implementation (Moore et al., 2015). Monitoring the precise physiological (e.g., HR, RPE, blood lactate) and psychological (i.e., enjoyment) responses during training sessions enables practitioners and researchers to understand the internal load imposed on players and optimize and adjust designed training programs when needed (Reina et al., 2020; Twist et al., 2023). This is particularly important for SSG intervention given its predominant use in basketball.

To date, numerous studies have focused on determining the influence of team sizes, court size, game rules, and work: rest time on the physiological demands and perceived exertion encountered by players during SSG (Clemente, 2016; O'Grady et al., 2020). The findings from the majority of studies suggest that SSG with smaller team sizes (e.g., 2 vs. 2, 3 vs. 3; Klusemann et al., 2012; Conte et al., 2016), bigger playing areas (Atli et al., 2013) and longer duration bouts (Klusemann et al., 2012) can evoke higher HR and self-perceived exertion (RPE) responses. Moreover, the game rules of time constraints (Camacho et al., 2020) and dribbling prohibitions (Conte et al., 2015) were utilized to increase HR responses. However, few studies have compared the impact of different training approaches (e.g., SSG vs. HIT) on exercise intensity in male/female basketball players, showing that SSG and HIT elicited similar HR responses (Delextrat and Martinez, 2014). Nonetheless, inconsistent results in RPE of the two training approaches remain in existing studies, with RPE of HIT higher than or similar to that of SSG (Delextrat et al., 2018; Arslan et al., 2020). Thus, more studies are needed to determine the physiological and perceived exertion responses during SSG and HIT training.

On the other hand, psychological responses during and following exercise are seen as key factors for predicting future exercise intentions, behavior, and adherence (Stork et al., 2018). Specifically, the enjoyment towards an exercise, as usually determined by physical activity enjoyment scale (PACES), is an important predictor of exercise motivation and adherence (Selmi et al., 2020), both of which can lead to players continuing to play at the professional stage. Previous research found that SSG were more enjoyable (higher PACES) than HIT in soccer players (Los Arcos et al., 2015; Arslan et al., 2020). Also, it was observed that SSG provided higher enjoyment than HIT in young tennis players (Kilit and Arslan, 2019). Although these studies (Kilit and Arslan, 2019; Arslan et al., 2020) provided useful insight into enjoyment responses during SSG and HIT, no data were provided across all sessions per week during a longer training period (e.g., 4 weeks). In addition, there is a lack of data detailing players' enjoyment responses in female basketball players, thus calling for further investigation in this area.

Therefore, we aimed to examine the acute physiological, perceived exertion and enjoyment responses of female basketball players in 4-week SSG or HIT programs. It was hypothesized that SSG and HIT would elicit similar physiological and perceived exertion responses, while SSG would have higher enjoyment responses than HIT in each training session. In addition, the hypothesis was based on the self-determination theory (SDT; Deci and Ryan, 2000) that provides theoretical framework for understanding potential differences in induced psychological outcomes (i.e., perceived exertion and enjoyment) between SSG and HIT. In brief, it is known that stimulating environmental factors can facilitate the satisfaction of the three basic psychological needs (i.e., autonomy, competence and relatedness) and when they are met they increase self-determined (autonomous), intrinsic motivation, which in turn positively affects perceived effort and enjoyment response (Deci and Ryan, 2000; Sarrazin et al., 2002; Pope and Wilson, 2012; Sheldon et al., 2013; Monteiro et al., 2018; Lourenço et al., 2022).

2. Materials and methods

2.1. Participants

This study was based on a randomized parallel matched-group design. Generally, 24 female collegiate basketball players were recruited from one basketball team competing in a regional league. Players were matched based on their playing positions (center, forward, and guard) and training years, and then randomly assigned to a HIT group ($n = 12$) or a SSG group ($n = 12$). The inclusion criteria included regular participation in training sessions and tournaments, and no lower limb injury and/or surgery happened in the past 6 months. The exclusion criteria for players' data analysis included more than twice missing training ($n = 3$) or occurring lower limb injuries ($n = 2$). Thus, the final sample included 19 players (SSG: $n = 9$, age 20.0 ± 1.3 years, height 166.1 ± 6.6 cm, weight 59.2 ± 9.2 kg, maximal HR [HR_{max}] 198 ± 6.1 b min^{-1}, maximal oxygen uptake [VO_2 max] 44.4 ± 1.2 mL/kg/min, training experience 5.8 ± 2.0 years; HIT: n = 10, age 19.8 ± 0.8 years, height 165.1 ± 5.5 cm, weight 56.6 ± 11.0 kg, maximal HR [HR_{max}] 198.9 ± 4.8 b•min^{-1}, maximal oxygen uptake

[VO_2 max] 43.8 ± 1.4 mL/kg/min, training experience 5.6 ± 1.8 years). Verbal inquiries by the coaching staff revealed that players' menstrual cycles were stable in the past 3 months, and they normally participated in training and competitions during menstrual cycles. All players were informed about the experimental procedures, potential benefits, and risks before providing written consent to participate. Players were made aware that they could withdraw from the study at any time without penalty. The study was approved by the ethical standards of the local ethical committee (Number: IR00350-SPT-2020) and followed to the recommendations of the Declaration of Helsinki.

2.2. Variables

One week before the intervention period, body height (BH), body mass (BM), maximum heart rate (HR_{max}) and maximum running velocity (V_{IFT}) during the 30–15 intermittent fitness test (30-15_{IFT}) were assessed. BH was measured to the nearest 0.1 cm with a portable stadiometer (Seca, mod206 Birmingham United Kingdom) and BM to the nearest 0.1 kg with a portable scale (Seca, mod762, Birmingham United Kingdom). Players' HR was measured during training, while their perceived exertion (RPE) and enjoyment responses were measured after training.

Players' HR_{max}, V_{IFT} and aerobic fitness were estimated using the 30-15_{IFT} (Buchheit, 2010). The test has been shown to have high reliability (ICC = 0.96; Buchheit, 2010). It was performed on a full basketball court (28 × 15 m) and consisted of 30-s shuttle run separated by 15-s passive recovery. The initial velocity was set at 8 km/h and increased by 0.5 km/h every 45 s thereafter. The test was terminated when players were unable to sustain the requisite running speed. HR at that time was recognized as HR_{max}, while the velocity obtained in the final fully completed stage was taken as V_{IFT}. The HR responses were assessed using Polar V800 (Polar Electro Oy, Finland) and then exported and analyzed using Kubios HRV Standard 3.4.1 (University of Eastern Finland, Kuopio, Finland). To estimate mean heart rate (HR_{mean}, beats/min) and the percentage of maximal HR (%HR_{max}) reached in each SSG and HIT session, players' HR responses were continuously monitored (Reina et al., 2018, 2020).

Players' RPE was assessed using the Borg CR-10 category-ratio scale, which ranges from "very light activity" (1) to "max effort activity" (10; Borg, 1998). Players were required to verbally express their RPE immediately after each SSG and HIT session. Players had used the CR-10 for 4 weeks prior to the study to evaluate their regular exercise intensities.

Players' enjoyment responses to training were determined using a short–term PACES (Graves et al., 2010). Players filled out the PACES anonymously 3 min after each SSG and HIT session. The short-term PACES includes 5 items scored on a 1–7 Likert scales, and the total enjoyment responses for each training and for each player were summed to yield a score ranging from 5 to 35 (Graves et al., 2010). Players filled out the PACES anonymously to ensure the accuracy of perceived enjoyment. The PACES has been found to have high reliability and validity in physical activity environments (Kendzierski and DeCarlo, 1991).

2.3. Training programs

The 4-week training program was conducted during the pre-season. A typical week during this period consists of four 2-h training sessions that include various intensities of running, core conditioning, specific technical and tactical drills, and matches. SSG or HIT were performed 3 times per week in addition to regular practice sessions. Both interventions followed a progressive overload plan involving gradual increase in training stress (e.g., exercise duration, number of bouts and repetitions) over time (Figure 1). The design of the training matched duration in SSG and HIT was based on the recommendations of previous studies (Buchheit et al., 2009; Delextrat and Martinez, 2014). SSG and HIT were always performed at the beginning of each training session after a 15-min standardized warm-up that includes low-intensity running, dynamic stretching, and ball practice (dribbling, shooting, and layup). Prior to the training interventions, players have trained for 4 weeks to prepare their bodies for the intense exercise.

The SSG sessions involved 2 players per team (2 vs. 2) on half of the basketball court (15 × 14 m). Drills were played like a competition continuously for 2 min45 s–3 min45 s, followed by 2-min passive recovery between bouts. Scores were kept during games and strong verbal encouragements were provided by the coaching staff to improve players' motivation. Each SSG was refereed by assistant coaches who were qualified to referee. The following SSG rules were adopted: (a) only man-to-man defense to standardize technical–tactical parameters (Conte et al., 2015); (b) no free-throws or time-outs (Delextrat and Kraiem, 2013); (c) the shot clock was set to only 12 s (Klusemann et al., 2012); (d) if an offensive rebound was obtained, the players could continue to attack the basket directly; (e) if a defensive rebound was obtained or points scored, the players had to take the ball to the center circle before attempting to score; (f) after a change of possession (e.g., steal, defensive rebound) or points scored, players were allowed to steal the ball from the team attempting to bring the ball to the center circle; (g) in the event of fouls, turnover or ball out-of-bounds, the game was restarted when an offensive player ran to the nearer sideline and caught the spare ball from an assistant (Conte et al., 2016). During each SSG session, players were randomly assigned a pairing (consisting of a guard, and either a forward or a center), and new pairings were formed in the following session.

The HIT sessions included a series of intermittent running at 90–95% of players' V_{IFT} for 15 s on a 20-m-long field integrating 180° changes of direction, followed by 15-s passive recovery. During each 15-s running, players should start from their own position (based on their target running distance) and finish all together on the same line. During the 15-s recovery period, players should walk to their starting line and wait for the next 15-s running.

2.4. Statistical analysis

Data analyses were performed using the open-source statistical software JASP.[1] The normality of all data was checked using the Shapiro–Wilk test. The homogeneity of variance was confirmed with a Levene test. Mixed two-way ANOVAs with one "between" factor (group: SSG and HIT) and one "within" factor (time: week 1, 2, 3 and 4) was used to determine changes in physiological, perceived exertion and enjoyment responses in both interventions. Significant effects were

1 http://www.jasp-stats.org

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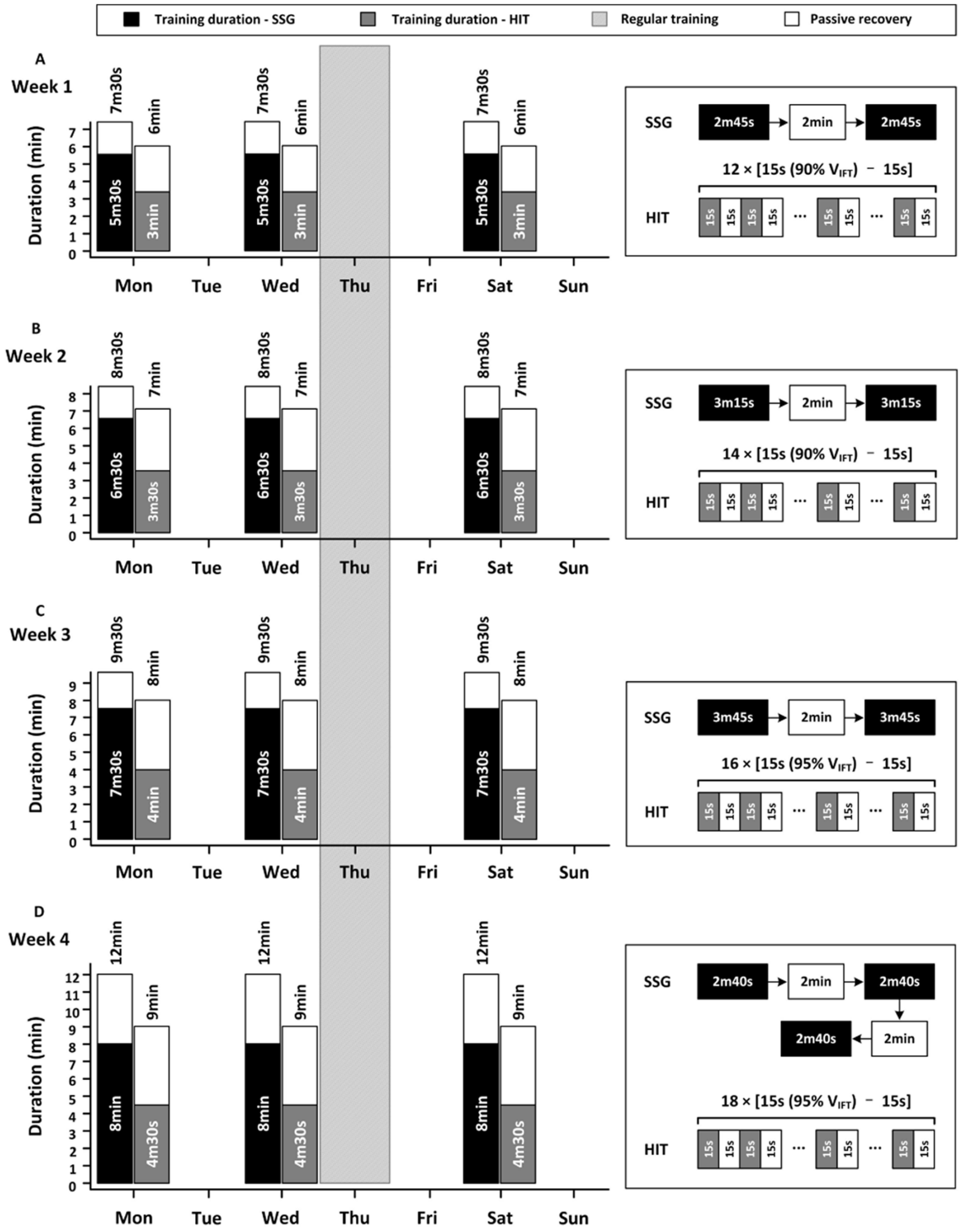

FIGURE 1
The training duration and regimen of each SSG and HIT session (Monday, Wednesday, and Saturday) in week 1 **(A)**, week 2 **(B)**, week 3 **(C)**, and week 4 **(D)**. Only regular training program performed in Thursday; 12×[15s (90%V_{IFT}) – 15s] means 12 bouts of 15-s high-intensity running at a speed equal to 90% of the speed achieved in the final completed stage of the 30–15 intermittent fitness test, followed by 15-s passive recovery.

subsequently examined using the Bonferroni post-hoc test. Partial eta squared (η_p^2) was calculated to estimate main effects and interaction effects. The thresholds for η_p^2 were as follows: <0.04, no effect; 0.04–0.25, minimum effect; 0.25–0.64, moderate effect; >0.64, strong effect (Ferguson, 2016). Hedges' *g* was used to indicate the effect size for pairwise comparisons and interpreted as followed: <0.2, trivial; 0.2–0.6, small; 0.6–1.2, moderate; 1.2–2.0, large; >2.0 very large (Hopkins et al., 2009). The level of significance was set at $p < 0.05$. Data were presented as mean and standard deviation ($M \pm SD$) or mean difference (*MD*) and 95% confidence intervals (95% *CI*).

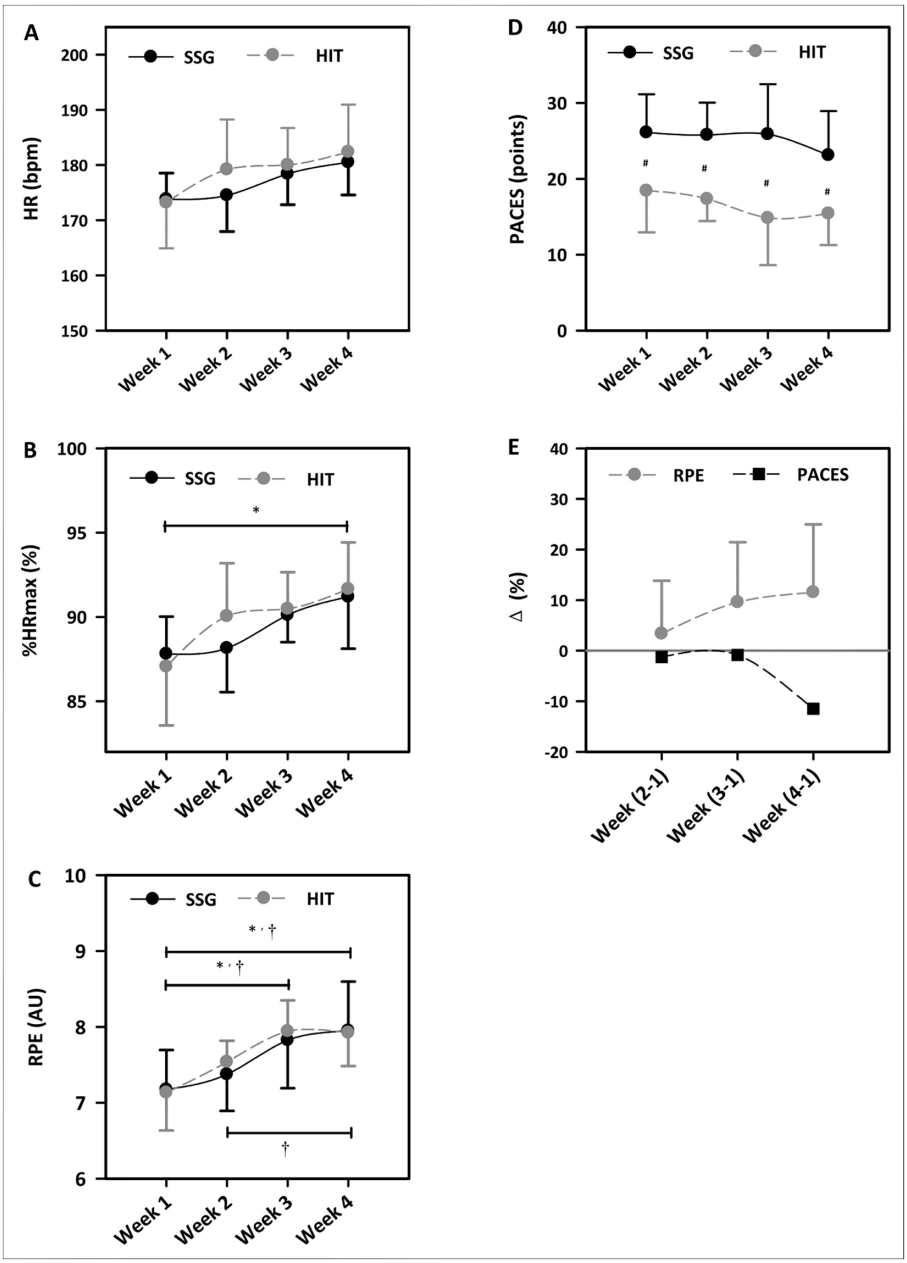

FIGURE 2
HR_{mean} **(A)**, $\%HR_{max}$ **(B)**, RPE **(C)**, and PACES **(D)** recorded in the SSG and HIT groups, and %change of RPE and PACES **(E)** in the SSG group during the 4-week training period. Week (2–1): the PACES or RPE of the SSG group in week 2 minus that in week 1; SSG: small-sided game; HIT: high-intensity interval training; *significant differences within the HIT group; †significant differences within the SSG group; #significant differences between the SSG and HIT groups; error bars for HR_{mean}, $\%HR_{max}$, RPE, and PACES is standard deviation (*SD*).

3. Results

3.1. Physiological responses

There were no significant interactions (group × time) and main group effects in HR_{mean} (Figure 2A) and $\%HR_{max}$ (Figure 2B). A main time effect was found in HR_{mean} ($p = 0.004$; $\eta_p^2 = 0.16$, minimum) and $\%HR_{max}$ ($p < 0.001$; $\eta_p^2 = 0.25$, minimum), respectively. Although no within-group differences were found in $\%HR_{max}$ responses during the 4-week intervention, $\%HR_{max}$ in the SSG group were below 90% in week 1 (87.8 ± 2.2%) and week 2 (88.1 ± 2.6%), respectively. $\%HR_{max}$ in the HIT group was significantly lower in week 1 than that in week 4 (*MD*: −4.60; 95%*CI*: −8.21 to −0.99; $p = 0.005$; $g = 1.46$, large).

3.2. Perceived exertion responses

There were no interactions and main group effects in RPE, but there was a main time effect ($p < 0.001$; $\eta_p^2 = 0.31$, moderate; Figure 2C). RPE was significantly lower in week 1 than that in week 3 (*MD*: −0.65; 95%*CI*: −1.13 to −0.17; $p = 0.001$; $g = 1.12$, moderate) and week 4 (*MD*: −0.78; 95%*CI*: −1.25 to −0.30; $p < 0.001$; $g = 1.32$, large)

in the SSG group, and RPE was lower in week 2 than that in week 4 (*MD*: –0.58; 95%*CI*: −1.05 to −0.10; $p = 0.008$; $g = 1.25$, large). In addition, RPE in the HIT group was lower in week 1 than that in week 3 (*MD*: -0.81; 95%*CI*: −1.23 to −0.40; $p < 0.001$; $g = 1.77$, large) and week 4 (*MD*: -0.79; 95%*CI*: −1.21 to −0.37; $p < 0.001$; $g = 1.67$, large), respectively.

3.3. Enjoyment responses

A main group effect was found in PACES ($p < 0.001$; $\eta_p^2 = 0.44$, moderate), but no interactions and main time effects were noted (Figure 2D). SSG elicited significantly higher PACES than HIT in week 1 (*MD*: 7.70; 95%*CI*: 0.64 to 14.75; $p = 0.03$; $g = 1.45$, large), week 2 (*MD*: 8.44; 95%*CI*: 1.39 to 15.50; $p = 0.01$; $g = 2.39$, very large), week 3 (*MD*: 11.06; 95%*CI*: 4.00 to 18.11; $p < 0.001$; $g = 1.86$, large), and week 4 (*MD*: 7.70; 95%*CI*: 0.64 to 14.75; $p = 0.03$; $g = 1.56$, large), respectively.

Figure 2E presents %change (%Δ) of RPE and PACES of the SSG group in week 2 (2–1), week 3 (3–1), and week 4 (4–1) minus week 1. %change of RPE shows an increasing trend ($\%\Delta_{2-1} = 3.35$, $\%\Delta_{3-1} = 9.58$, $\%\Delta_{4-1} = 11.53$, respectively) and %change of PACES shows a decreasing trend ($\%\Delta_{2-1} = -1.28$, $\%\Delta_{3-1} = -0.85$, $\%\Delta_{4-1} = -11.49$, respectively).

4. Discussion

To our knowledge, this is the first study to investigate the acute physiological, perceived exertion and enjoyment responses of female basketball players in 4-week SSG or HIT training programs. Our findings show that SSG was perceived as more enjoyable than HIT as indicated by PACES. SSG and HIT elicited similar physiological and perceived exertion responses, as no significant differences in HR_{mean}, $\%HR_{max}$ and RPE were found between groups in each week. Although comparisons across time points revealed non-significant differences in HR_{mean} and $\%HR_{max}$, SSG elicited HR_{max} response below 90% in the first and second week. Lower HR_{max} responses in the first and second week were accompanied by lower RPE.

Our data show that SSG elicited significantly higher enjoyment responses than HIT in each week of the training intervention. Although there was no data in basketball, our findings are consistent with other research comparing the enjoyment responses between soccer or tennis SSG and HIT (Los Arcos et al., 2015; Kilit and Arslan, 2019; Arslan et al., 2020). From a theoretical point of view, based on the Self-determination theory (Deci and Ryan, 2000), it seemed that SSG (i.e., the presence of ball, teammates and opponents, and the replication of game-like scenarios) result in satisfaction of basic psychological needs—BPN (i.e., autonomy, competence and relatedness) that increased intrinsic motivation and enjoyment response. In brief, feeling of autonomy and relatedness could be easily satisfied in SSG where the players had a freedom to regulate their own actions (e.g., dribbling, shooting) and feel affiliated and connect to the team, respectively. Likewise, in 2 vs. 2 scenario players were able to showcase their basketball ability more frequently than in a 5 vs. 5 scenario, in which they might not have as many chances to score or be creative, which could satisfied their psychological need for competence. It can be speculated that SSG provided stimulating, learning and challenging environment that facilitated satisfaction of BPN, which in turn could increase intrinsic (i.e., autonomous) motivation and therefore positively affect enjoyment response (Selmi et al., 2020) and perceived effort (Monteiro et al., 2018). Moreover, it is reasonable to believe that athletes recognized SSG as meaningful activities and training environment that provided opportunities for learning new sport-specific skills which could induce long-lasting motivation (Dismore and Bailey, 2011). Therefore, SSG seems a more effective training method than HIT (i.e., simply running at predetermined intensity) for increasing exercise motivation and adherence. We recommend that coaches schedule SSG training more frequently than HIT for players who regularly participate in training and competitions in order to maintain players' exercise enthusiasm.

Similar physiological and perceived exertion responses in SSG and HIT observed in our study indicates that the two training approaches could elicit similar physiological training stimuli. Despite the fact that there are fewer studies on female basketball players (Reina et al., 2020), making it difficult to compare players of similar levels, our findings are consistent with other research investigating male basketball players (Delextrat and Martinez, 2014; Delextrat et al., 2018) and male soccer players (Dellal et al., 2012). In contrast, some studies indicated that SSG could elicit lower perceived exertion compared with HIT since it is more enjoyable (Kilit and Arslan, 2019; Arslan et al., 2020). The similar perceived exertion between the two training approaches in our study could be explained by the fact that the SSG format (2 vs. 2) results in higher training intensity than formats including larger team sizes (Castagna et al., 2011; Klusemann et al., 2012).

SSG elicited $\%HR_{max}$ responses below 90% in first and second week. Given the notion that training at high HR zones (above 90% of HR_{max}) is considered to be more effective than lower HR zones (Delextrat and Kraiem, 2013; Malone et al., 2019), cardiovascular stimuli in the first 2 weeks were probably insufficient and needed to be optimized. Significant lower RPE in first and second week (7.2–7.4) compared with that in third and fourth week (7.8–8.0) also support the inference. Given that the main purpose of pre-season training is to develop sport-specific performance and maximize training effectiveness (Paul et al., 2019), it is practical to appropriately increase the training stimulus during the SSG intervention program. Researchers suggested that SSG with longer duration bouts could elicit greater physiological and perceived exertion responses (Klusemann et al., 2012; Conte et al., 2016). Given that SSG elicited above 90% of HR_{max} responses and 7.8–8.0 of RPE in third and fourth weeks, the duration of each bout of SSG in first and second weeks could be increased to achieve larger adaptations. Therefore, we infer that it would be appropriate to set the SSG duration at least 7.5 min in one training session during first week of the intervention, and gradually increase training durations in the subsequent weeks. Similar patterns could be used by researchers and practitioners to determine whether implemented training programs achieve optimal training stimuli, with the goal of optimizing intervention effectiveness.

Manipulating team sizes, court sizes, and rules could impact physiological and perceived exertion responses during SSG training (Clemente, 2016; O'Grady et al., 2020). In our study, 2 vs. 2 SSG was performed given that smaller team sizes allow for a larger relative playing area per player and greater freedom of movement, resulting in greater physiological and perceived exertion responses (Castagna et al., 2011). Furthermore, we used half-court (14 × 15 m) playing area to allow more technical actions performed (Klusemann et al., 2012; Atli et al., 2013) and more players simultaneously involved (up to 8 players performing 2 vs. 2 drills at the same time). Although full-court SSG are more likely to elicit greater training stimuli because of conducting

rapidly transitions up and down the court (Atli et al., 2013), researchers showed no differences in HR responses between full-court and half-court SSG (Klusemann et al., 2012; Bredt et al., 2020). In addition, we prescribed that no times-outs or free-throws were rewarded (Delextrat and Kraiem, 2013), the ball was replaced immediately when out of play (Conte et al., 2016), and a 12-s shot clock was used (Klusemann et al., 2012) to avoid interruptions and enhance the exercise intensity. We also arranged the regular offensive and defensive schemes (e.g., man-to-man defensive) to standardize technical–tactical parameters. As a result, half-court, 2 vs. 2 SSG combined with modified rules seems to preserve the relative consistency of SSG's content and assist players in receiving optimal cardiovascular stimuli while maintaining relatively high enjoyment during training.

From a practical perspective, coaches prefer to increase the frequency of SSG in training programs due to the desired cardiovascular stimulus and high enjoyment responses elicited during training. However, our findings show that gradually increased RPE was accompanied with decreased PACES during the 4-week progressive SSG intervention (Figure 2E). Research (Fernandez-Rio et al., 2014) also suggested that performing high-intensity training sessions for 3 weeks would lower self-determined motivation, which is mainly influenced by perceived enjoyment responses during training. Accordingly, we infer that progressive SSG interventions appear to slightly reduce enjoyment responses and motivation due to increased training intensities and loads. Furthermore, the high physiological and perceived exertion responses in SSG, combined with its frequent use, are likely to cause insufficient recovery and raise the potential risk of overtraining or injury (Clemente, 2016). Thus, monitoring acute physiological, perceived exertion and enjoyment responses during each training session is necessary to avoid overuse of SSG and is beneficial in determining its optimal dose.

5. Limitations

There are several limitations of the study that should be acknowledged. First, this study did not assess blood parameters (e.g., blood lactic acid) which could help in additional explanation of the underlying mechanisms of the physiological load. Second, the PACES was filled out anonymously, so the correlation between PACES and RPE could not be calculated. Third, the study was performed with sub-elite female basketball players and included a relatively small sample size, so extrapolation of the findings to elite and male players should be taken with caution. Forth, motivational factors were not measured which thwart establishing relationship between players´ motivation, satisfaction of basic psychological needs and enjoyment and perceived effort response in SSG and HIT. Finally, the study did not incorporate measurements of players´ external load during SSG, which could help to additionally explain the obtained results.

6. Conclusions and practical application

Overall, SSG and HIT elicit similar physiological and perceived exertion responses during training sessions, but SSG is more enjoyable and therefore it is more likely to increase exercise motivation and adherence comparing to HIT. The current study encourages practitioners and researchers to incorporate SSG training programs during pre-season for collegiate female basketball players. It seems that half-court, 2 vs. 2 SSG training format with modified rules and lasting $\geq$ 7.5 min should be prescribed as an enjoyable training alternative to provide optimal cardiovascular stimuli (> 90% of HR_{max}) for female basketball players. Coaches should frequently ask basketball players to set the playing rules by themselves during SSGs, which in turn could increase their autonomous (i.e., intrinsic) motivation and therefore positively affect enjoyment response and perceived effort. Moreover, we recommend coaches to use SSGs as training environment that provides opportunities for learning and improvement of specific skills (e.g., dribbling and/or scoring only with a non-dominant hand) and implementation of new tactical ideas and concepts both in offense (e.g., scoring only after pick and roll play) and defense (e.g., switching or setting a trap). In this way, players may recognize the training setting as constructive, beneficial and meaningful, which could induce long-term motivation and improvement.

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 Regional Ethical Review Board in Hangzhou (IR00350-SPT-2020). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JZ, FX, and JX: conception and design. JZ and FX: analysis and interpretation of the data. JZ, HP, and FX: drafting the article and revising it critically for important intellectual content. 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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Association of self-efficacy and mental toughness with sport performance in Brazilian futsal athletes

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Introduction: Self-efficacy is considered a component of mental toughness, but there are few studies investigating the relationship of sport self-efficacy with mental toughness in performance athletes, especially in team sports.

Objective: The objective was to examine the impact of sport self-efficacy mediated by mental toughness on the sport performance of Brazilian futsal athletes.

Methods: The sample was composed of five adult male teams participating in the National Futsal League 2020, totaling 77 athletes. As instruments, we used: athlete identification sheet, Perceived Self-Efficacy Scale in Sports (PSES), Mental Toughness Index (MTI) questionnaire and the performance data from the National Futsal League 2020 (NFL). The data were analyzed using the Kolmogorov–Smirnov test, Mann–Whitney "U" test, Spearman's correlation, network analysis (LASSO), with the indicators of centrality: strength, proximity and degree of intermediation ($p<0.05$).

Results: The results showed that the investigated sample presented high levels of Perceived Self-Efficacy Scale in Sports (PSES) (Md= 4.66) and mental toughness (MT) (Md= 6.44). PSES presented a positive relationship with the number of wins, and negative relationships with the number of red cards and wrong passes (r =−0.08). MT indirectly influenced these variables through its connection with PSES (r = 0.30). The best ranked teams presented higher amounts of goals for, fouls, shots on goal, tackles, assists, and wins. The time of practice revealed an inverse relationship with the number of defeats, while age was positively related to the number of wrong passes (r=0.09). The centrality indicators showed that the number of games stood out as the most central variable in the network, due to its degree of strength, proximity and intermediation. Moreover, the high degree of proximity and intermediation of the tackles made presented a connection with the number of assists (γ=0.25; n=77).

Conclusion: We can conclude that sport self-efficacy and mental toughness are intervening factors in the sport performance of Brazilian futsal athletes.

KEYWORDS

sport self-efficacy, performance, futsal, mental toughness, Brazilian athletes

Introduction

Self-efficacy (SE) plays a key role in terms of understanding the dynamics and performance of sport teams (Jowett et al., 2012), in that it influences athletes' decision-making, motivation, sport engagement, as well as collective performance and the way in which they will deal with sport failures (Alves et al., 2021). SE is considered a component of mental toughness (MT) (Crampton, 2014; Whitton et al., 2020), but there are few studies investigating the relationship of sport self-efficacy with mental toughness in performance athletes, especially in team sports.

Recent research has investigated SE in relation to quality of life in volleyball athletes (Aizava et al., 2021); systematic review on collective efficacy in soccer teams (Alves et al., 2021); confidence in using apps for health and sport (Chamorro-Koc et al., 2021); competitive cognitive anxiety, motor performance and goal orientations in college basketball (Peng and Zhang, 2021); health-related behavior in Taekwon-Do (Ortenburger et al., 2021). Accordingly, the present study aims to explore this gap by investigating the impact of self-efficacy mediated by mental toughness on the sport performance of Brazilian futsal athletes.

Until this moment, we have found two studies investigating both variables in ultramarathon runners (Brace et al., 2020), while Ramolale et al. (2021) examined the mediating role of MT in the relationship between self-efficacy and pro-social/antisocial behaviors in young athletes in Botswana. The authors pointed out the need to advance these investigations, highlighting a paucity of studies relating self-efficacy to mental toughness.

In this regard, Bandura et al. (2008) sought to explain the perception (belief) of SE through the Social Cognitive Theory (SCT) and the Triadic Reciprocal Model (TRM), in which thinking and behavior are products of the dynamic and reciprocal interrelationship between personal, behavioral and environmental influences. This perception determines the judgment of the ability of individuals to perform a certain task, directly influencing the results that these people expect to achieve with the joint actions (Bandura, 1977).

In the context of performance athletes, MT has an important role for good levels of sports performance, helping to deal with adverse situations: coping with stress, frustrations, challenges and everyday adversities, being essential for sporting success (Moreira et al., 2021). According to Gucciardi (2017), considering that MT is a dynamic and adaptive psychological resource, the investigation of this variable in athletes is essential, making it possible to evaluate clear objectives with efficiency in terms of developing and maintaining good decision-making (Anthony et al., 2020).

As hypotheses, it is expected that athletes present a good perception of sports self-efficacy and mental toughness, and that there is a good association between these variables, in addition to interactions with sports performance. Thus, the objective of this study was to examine the impact of sport self-efficacy mediated by mental toughness on the sport performance of Brazilian futsal athletes.

Materials and methods

Population and sample

The target population was composed of 252 athletes from the National Futsal League 2020 (NFL 2020). This competition was chosen because it is the main futsal competition in Brazil. Currently, the Brazilian men's futsal team is the best team in the world in the world ranking of futsal teams, according to the Fédération Internationale de Football Association (FIFA, 2022), making the National Futsal League one of the most important leagues around the world.

As inclusion criteria were considered: being over 18 years old, having active and regular contracts in the teams and participating in the league. The following were excluded: athletes under the age of 18, athletes who were not participating in the league (due to contractual or injury reasons), athletes on leave due to Covid.

The sample was composed of 77 athletes with a mean age of 27.6 years (±4.6), who consented to participate in the study, belonging to five teams (each team had between 14 and 16 athletes). Due to the paralysis of the NFL 2020 as a result of the COVID-19 pandemic, all teams reported being with a reduced cast in relation to the original cast, because of the termination of contract of some athletes and consequent spending cuts.

Instruments

The instruments used were the athlete identification sheet, the Perceived Self-Efficacy Scale in Sports (PSES), the Mental Toughness Index (MTI) questionnaire and the performance data made available on the National Futsal League (NFL) 2020 website.

Athlete identification sheet

We used an identification sheet to record the athletes' personal data such as age, position, time of practice and forms of contact (*e-mail, Whatsapp*).

Perceived self-efficacy scale in sports

The Physical Education Efficacy Perceptions (PEEP) was initially developed by Jackson et al. (2012). This instrument is part of a series of analyses called Tripartite Efficacy Beliefs (TEB).

Three instruments were developed to evaluate perception and self-efficacy: self-efficacy perception (self-efficacy), athletes' confidence in coaches' efficacy (other-efficacy) and estimation of coaches' confidence in their abilities (relation-inferred self-efficacy—RISE). The present study addressed the instrument that evaluates self-efficacy in itself, with adaptation and validity evidence for the sport context.

After the process of cross-cultural adaptation and validity evidence (Aizava, 2022), we observed that the Perceived Self-Efficacy Scale in Sports (PSES) presented good psychometric properties for its use in the sport context and all items were maintained. The nine questions are answered on a 5-point Likert scale: ranging from 1 (no confidence), 2 (low confidence), 3 (moderate confidence), 4 (high confidence), and 5 (total confidence), and their result is unifactorial through the overall mean of the questions (1–5).

Strong reliability was shown with Cronbach's Alpha values, all above $\alpha > 0.70$. Through the analysis of factorial loads obtained in the final model, the Composite Reliability (CR) obtained satisfactory values (CR = 0.87), and the Mean Extracted Variance (MEV) presented

values within the limits recommended by the literature (MEV = 0.44). The instrument presented a value of $\alpha = 0.791$, showing strong data reliability for the present study.

Mental toughness index

In order to evaluate mental toughness, we applied the Mental Toughness Scale (MRS) initially developed by Gucciardi (2012) for the English language and validated for the Brazilian context by Moreira et al. (2021).

The scale contains eight questions about how the athlete generally thinks, feels and behaves during a sport practice, answered on a Likert scale from 1 to 7, and its result is given in a unidimensional form from the overall mean of the questions.

Mental toughness (MR) was rated at: 1 to 2—low; 3 to 4—medium; 5 to 7—high. The instrument showed a value of $\alpha = 0.764$, demonstrating strong data reliability for the present study.

Performance data—National Futsal League 2020

The athletes' sports performance was obtained after the end of the NFL 2020. The data was collected through the website https://ligafutsal.com.br/estatisticas/, with information such as: final ranking, goals scored, fouls committed, fouls conceded, cards received, assists, tackles, and defenses.

Data collection

The present research is part of the institutional project called "Development process of positive psychological variables in the sport context" (Opinion no 4.022.246). Considering that the collection took place during the pandemic period of COVID-19, we adopted a biosafety protocol with some precautionary and preventive measures, following the recommendations of the World Health Organization (WHO) for face-to-face collections:

- Prior scheduling and authorization from the teams' supervisors, in a suitable place and time, avoiding crowds and wearing masks.
- Hand sanitization with alcohol gel 70° INPM for all research participants, before and after completing the questionnaires, as well as for the researcher.
- All questionnaires and pens were previously sanitized with alcohol 70° INPM and placed in individual plastic envelopes.
- The individual envelopes were placed on a table, or directly on the tables where each athlete would sit, so that each athlete could take his/her questionnaire, avoiding direct contact with the researcher and maintaining a distance of 2 m.
- After the collections, all pens were placed in a separate container for immediate sanitization with alcohol 70° INPM.
- All questionnaires (paper) were placed in a separate envelope and handled only after 5 days. After this period, the envelope was discarded and the questionnaires were stored in a new envelope.

Some questionnaires were sent via e-mail, completed, scanned and sent back to the researcher; other questionnaires were sent via e-mail, and later the researcher picked them up in person with the supervisor/technical coordinator. The data were collected individually, during the second semester of 2020, according to the availability of the athletes by completing the Free and Informed Consent Form (FICF).

Data analysis

Data were evaluated using descriptive statistics (median and interquartile range) and inferential statistics through specific statistical parameters established by the Kolmogorov–Smirnov normality test ($n > 50$), in which the data presented a non-parametric distribution. Cronbach's Alpha coefficient was used to verify data reliability, in addition to Mann–Whitney's "U" test, Spearman's correlation coefficient and network analyses ($p < 0.05$).

In order to verify the multivariate relationships between the investigated variables, the network analysis method was used. From the previously calculated Spearman's correlation matrix, regularized networks of partial correlations called LASSO networks (Least Absolute Shrinkage and Selection Operator) were computed. LASSO regularization is a method used to control the presence of spurious correlations by reducing the partial correlation coefficients to zero, removing weak and trivial connections, and favoring simpler and more objective networks to be interpreted (Epskamp and Fried, 2018).

In order to configure the network selection, it is possible to adjust the hyperparameter γ (gamma). Higher values of gamma ($\gamma = 0.5$) result in simpler networks, with fewer connections and greater parsimony, also called a sparse network, which means that spurious correlations (false positive) will hardly be preserved; however, there is the possibility that true connections are also lost (false negative); on the other hand, lower values of gamma ($\gamma = 0$) favor the discovery of connections, although it requires greater caution when interpreting them (Epskamp and Fried, 2018). In this regard, three network models were computed with increasing values of gamma, from the least to the most conservative: Network 1 with $\gamma = 0$, Network 2 with $\gamma = 0.25$ and Network 3 with $\gamma = 0.5$. For the present study, we consider the network with $\gamma = 0.25$, as it is considered a more balanced network in its connections.

In general, networks are formed by "nodes" (circles representing variables) connected by edges, whose color and thickness vary according to the direction and intensity of the relationship between these variables, and the distribution and proximity of the nodes also correspond to the associations within the network (Silva et al., 2006). In order to identify the most influential or most important variables, we used the following network centrality indicators (NCI): Strength, which evaluates the sum of the weights/coefficients of each node; Proximity (Closeness), which evaluates the distance (length of the edges) connecting a node with the others and indicates the speed with which its information propagates in the network; and degree of intermediation (Betweenness), which represents the number of times a node acts as a bridge/connector on the shortest path between two nodes, that is, how much information passes through that variable within a network, indicating its potential to affect the other variables (Dalege et al., 2017).

TABLE 1 Descriptive analysis of perceived self-efficacy scale in sports (PSES), mental toughness (MT) and performance data of NFL 2020 teams from Paraná (n=77).

	PSES		MT		G. F.	Y. C.	R. C.	F	S. G.	T.S.	A	W	D	D	G	F. R.
	Md	(Q1–Q3)	Md	(Q1–Q3)												
Team 1	4.60	(3.92–4.80)	6.50	(5.82–6.80)	51	46	1	124	211	1,145	28	8	3	5	16	5°
Team 2	4.65	(4.32–4.77)	6.40	(6.15–6.75)	28	42	4	119	218	1,084	15	4	8	4	16	7°
Team 3	4.90	(4.67–5.00)	6.70	(6.22–6.85)	31	28	2	101	168	1,005	23	5	5	4	14	9°
Team 4	4.30	(4.20–4.60)	6.10	(5.90–6.50)	22	27	1	93	157	957	14	3	5	6	14	16°
Team 5	4.85	(4.50–4.92)	6.50	(6.10–6.82)	24	24	2	74	130	748	7	4	0	8	12	17°

PSES, perceived self-efficacy ecale in sports; MT, mental toughness; G. P., goals for; Y. C., yellow cards; R. C., red cards; F, fouls; S.G., shots on goal; TS, tackles; A, assists; W, wins; D, draws; D, defeats; G, games; F. R., final ranking.

Results

The descriptive analyses allowed us to observe that the investigated futsal athletes had good levels of Perceived Self-Efficacy Scale in Sports (PSES) and Mental Toughness (MT) (Table 1).

Considering that PSES varies between 1 and 5 and MT varies between 1 and 7, PSES was rated as: 1 to 2—low; 3—mean; 4 to 5—high; MT was evaluated in: 1 to 2—low; 3 to 4—mean; 5 to 7—high. Table 1 shows that all teams had excellent levels of PSES and MT, with median PSES above Md = 4.30 and median MT above Md = 6.10.

It can be seen that the best ranked teams (teams 1, 2, and 3) had higher amounts of goals for (GF), fouls (F), shots on goal (SG), tackles (TS), assists (A) and wins (W). Teams 1 and 2 received the greatest numbers of yellow cards (YC), with 46 and 42, respectively. Team 1 received only one red card (RC), while team 2 received four red cards. On the other hand, teams 4 and 5, with the worst final ranking (FR), presented worse indexes in the same observed performance variables (Table 1).

In Figure 1, the analyzed model brings a greater balance between specificity and sparsity, with the hyperparameter gamma ($\gamma = 0.25$), in which the spatial distribution of the variables is observed, one of the indicators of their interrelationships. Age, time of practice and psychological characteristics were positioned at the upper left end of the network (close to red cards), while the number of games and their results (win, draw, or defeat) were grouped on the right side.

In terms of connections, we highlight some of the relationships that connect the different groupings of the network. The Perceived Self-Efficacy Scale in Sports (PSES) showed a positive relationship with mental toughness (MT) ($r = 0.30$), playing its role indirectly, through this connection. In addition, PSES showed connections with the number of wins ($r = 0.07$), a negative relationship with the number of red cards ($r = -0.08$) and wrong passes ($r = -0.06$); time of practice had an inverse relationship with the number of defeats ($r = -0.06$) and age was positively related to the number of wrong passes ($r = 0.09$) (Figure 1).

Figure 2 presents the Network Centrality Indicators (NCI).

The number of games played proved to be the most central variable in the network, due to its degree of strength, proximity and intermediation. The high degree of proximity and intermediation of the tackles made stands out, which was connected to the number of assists ($r = 0.08$). All correlations were significant ($p < 0.05$).

Discussion

The objective of this study was to examine the impact of Perceived Self-Efficacy Scale in Sports (PSES) mediated by mental toughness (MT) on sport performance in Brazilian futsal athletes. This is the first study to relate PSES, MT and performance in Brazilian futsal athletes using a specific instrument to investigate PSES.

In Table 1, it was possible to observe that the investigated sample presented high levels of PSES and MT. The best ranked teams (teams 1, 2, and 3) presented higher amounts of goals for, fouls, shots on goal, tackles, assists, and wins. It is noteworthy that futsal is an extremely dynamic sport, with extremely fast and constant motor actions, as well as the exchange of positions among athletes, especially during the offensive phase (Müller et al., 2018; Bueno et al., 2020).

The teams with the greatest number of goals, shots on goal and best final ranking also presented the greatest number of tackles, fouls, yellow cards and assists. This fact can be explained by the specificity of this modality, in which many tackles are made near the opponent's goal, which may result directly in a shot on goal or even an assist. Nevertheless, these technical gestures often end up generating a foul for the opposing team (Pizarro et al., 2020).

Borges et al. (2021) stated that futsal demands a great deal of energy from its athletes, both in the physical and mental aspects. Because it is an extremely dynamic sport, it is important that the athletes have a good PSES, as well as MT, as our findings showed. The mental skills of the athletes stand out when we observe that, even with a considerable amount of fouls, such penalties, generate few expulsions and, at the same time, create good offensive actions for the teams, showing that the athletes have good mental control and good decision-making in the choice of the sportive technical gesture, fundamental for a good athletic performance (Spyrou et al., 2020) (Table 1).

In the network analyses, the importance of the connections established by self-efficacy (SE) stands out. PSES showed a positive relationship with the number of wins, and negative relationships with the number of red cards and wrong passes. Mental toughness (MT) indirectly influenced these variables through its connection with PSES (Figure 1).

This shows that these athletes can obtain good levels of performance, through good relationships with the wins and fewer wrong passes. In addition, they have emotional and technical control to avoid expulsions. According to Uchida et al. (2018) Perceived Self-Efficacy Scale in Sports (PSES), relates to the individual's ability to self-regulate, due to his/her ability to control and modulate his/her

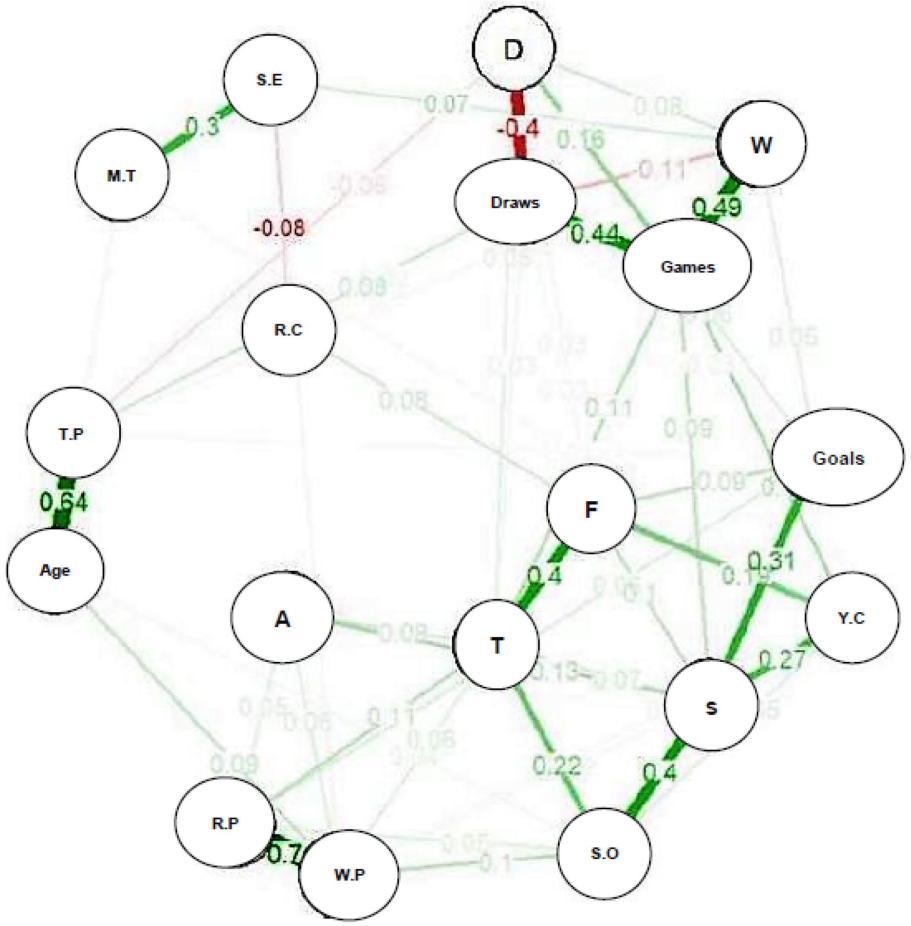

FIGURE 1
Perceived sport self-efficacy, mental toughness and performance data of the NFL 2020 teams from Paraná (γ=0.25; n=77). A, assists; D, defeats; F, fouls; M.T, mental toughness; R.C, red cards; R.P, right passes; S.E, self-efficacy; S.O, shots out; S, shots; T.P, time of practice; T, tackles; W.P, wrong passes; W, wins; Y.C, yellow cards.

behavior to achieve his/her goals and objectives, in addition to presenting better self-control and performance skills (Du and Zhang, 2022). Such findings are in line with recent research considering that high levels of SE are positively associated with success and better sport performance (SP) (Ayazi et al., 2013; Butt et al., 2017; Weight et al., 2020; Li et al., 2022).

The time of practice showed an inverse relationship with the number of defeats, while age remained positively related to the number of wrong passes (Figure 1). According to Aizava et al. (2021), athletes with longer experience in the sport tend to present a higher PSES, obtaining a better sport performance, which may explain the negative relationship with defeats (Arribas-Galarraga et al., 2020; Machado et al., 2021). However, in an investigation with psychological variables in women cyclists, Abenza-Cano et al. (2021) did not observe a significant relationship between age, time of practice and the performance of the athletes.

For Norheim et al. (2020), with advancing age, there is a gradual decrease in muscle strength and muscle power, especially in the lower limbs, resulting in a critical role in terms of determining the competitiveness and performance of athletes. Rey et al. (2022) found that players over 30 years of age show significantly lower performance in total traveled distance, high-intensity activities, sprint distance and number of accelerations and decelerations. However, there are few investigations about the alterations in the technical and tactical performance of athletes in relation to their chronological age. In this regard, it is observed that, for older athletes, some specific technical gestures may become more difficult due to the aging process itself, which brings physiological and physical alterations to individuals, influencing the quality of motor task execution (Lorenzo-Martínez et al., 2021; Borghi-Ricardo et al., 2022).

Our findings allow us to state that, despite the fact that older athletes present more passing errors, they are able to obtain better sporting success, due to the good relationship with the number of wins. According to Ayazi et al. (2013), this can be explained by the fact that PSES is inversely related to the fear of success, that is, athletes try to perform more motor actions, even more complex ones, becoming more susceptible to errors, but obtaining positive results in the end (Butt et al., 2017; Weight et al., 2020).

In this regard, the results allowed us to identify that having a tough mindset is important for the athlete to feel more self-effective, leading athletes to practical behaviors and results, due to the intermediation done by PSES in the connection between MT and other nodes in the network. According to Brace et al. (2020), judgments carried out by SE in the context of MT involve complex

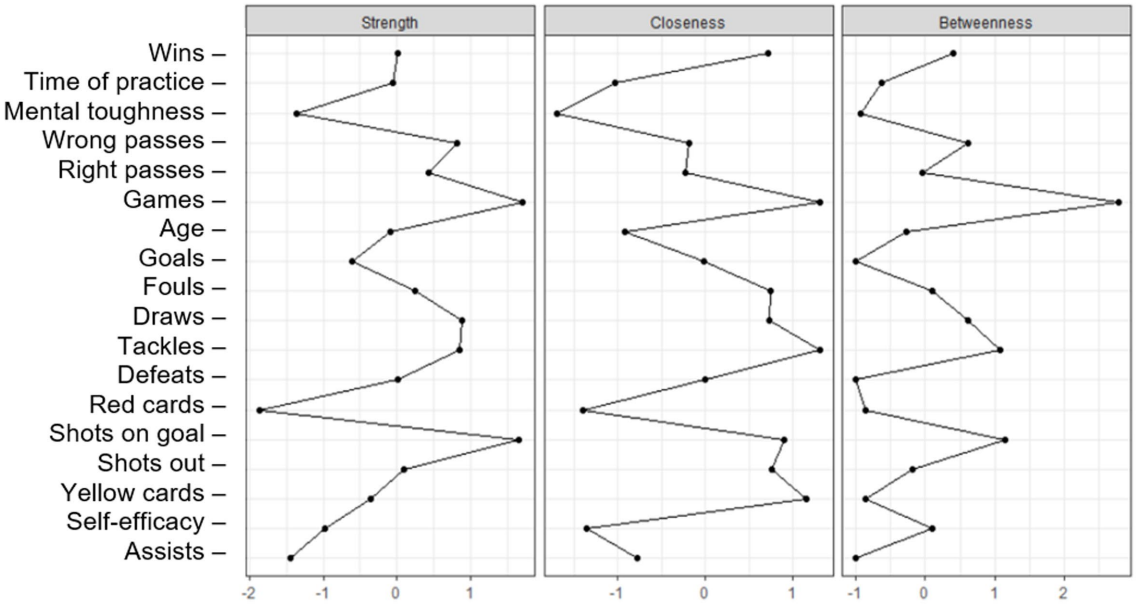

FIGURE 2
Network centrality indicators (NCI) of perceived sport self-efficacy, mental toughness and performance data of NFL 2020 teams from Paraná (γ=0.25; n=77).

processes of self-evaluations and persistence in extenuating circumstances.

Although still understudied, these factors are related to and influence the performance of other sport behaviors, and should be understood as shared attributes. Rintaugu et al. (2022) stated that having a tough mindset means being mentally strong, and that the athlete has acquired thinking, believing and visualizing skills that provide empowering emotions during competitions (Zeiger and Zeiger, 2018; Ramolale et al., 2021), in addition to showing better career development capacity, pressure resistance, training and good performance (Tian et al., 2022).

In study of Meggs et al. (2014), it was possible to identify, through self-report measures in 105 British athletes from different modalities (wrestling, swimming, dance, athletics, tennis, and rowing) in national level competitions, that MT was positively associated with psychological variables such as self-concept, and was particularly high in individuals with goal commitment, despite obstacles and the potential for failure. This reveals important implications for how beliefs about efficacy and MT interact and affect positive and pro-social behavior in sports. MT is an essential characteristic of the best athletes, who have better mental resources during performance sports (Kosirnik et al., 2022) and can be developed and improved over time, especially when there is a good relationship between coaches and athletes (Caruzzo et al., 2021).

We should also highlight the difference between the red cards and the other variables in the networks (Figure 1), due to its more isolated positioning, without establishing connections with the number of yellow cards, and with greater proximity to the psychological characteristics. This shows that athletes with good levels of SE and MT present imminent psychological characteristics in relation to the futsal game. They make many tackles during the matches, without making too many violent fouls or even pointing out emotional imbalances, which could result in more expulsions (Bueno et al., 2020; Pizarro et al., 2020; Spyrou et al., 2020; Borges et al., 2021).

In a study of elite figure skaters, Barkhoff and Heiby (2010) stated that PSES is directly linked to levels of competition. Their research showed that medal winning athletes (with better performance) revealed higher levels of PSES. It is noteworthy that, according to Han et al. (2022) regularly physically active individuals tend to have better PSES, as well as good mental health, important factors in SP. Nevertheless, Rogowska et al. (2022) identified that PSES more than simply is positively related to SP, but rather a predictor/mediator of performance.

The NCI (Figure 2) showed that the number of games played is the variable with the highest degree of power (strength) and intermediation (betweenness), and the second with the highest in degree of proximity (closeness). Tackling was the variable with the highest degree of closeness and the second with highest degree of intermediation, explaining its more centralized positioning in the networks.

Pizarro et al. (2020) emphasized the importance of defensive actions in futsal. Among them, tackling is one of the most important fundamentals. Our findings allowed us to show its importance for the other aspects of the game, by revealing connections with fouls, shots and the number of right passes, due to the specificity of this sport in which many times, when tackling, the athlete seeks an offensive pass, shots on goal, but it is an action that can result in a foul for the opponent if executed incorrectly (Bueno et al., 2020; Spyrou et al., 2020; Borges et al., 2021). The good levels of MT found are in line with the study of Rintaugu et al. (2022), in which the authors emphasized the importance of this variable in some team sports (soccer and handball), and that these tend to provide good MT to the athletes.

The current research presented some limitations regarding the sample size, which may be the main responsible for the disappearance of some connections as the parsimony of the network was increased, indicating that the observed relationships deserve to be tested again

in future studies with a larger number of observations to feed the network. In addition, the difficulties imposed by the COVID-19 pandemic (changes in the research project, target population, championship regulations, access to teams) certainly constituted a limiting factor for the development of the research.

Conclusion

The findings of the present research allowed us to observe that the investigated athletes of the NFL 2020 teams presented good levels of self-efficacy and mental toughness. The investigated teams performed well, with all teams staying in the league and some advancing to the final stages. Until this moment, all investigated teams remain in the main national futsal league in Brazil.

Through the network analysis, it was possible to note a good relationship between Perceived Self-Efficacy Scale in Sports (PSES) and mental toughness (MT), in which having a tough mindset seems to be important for a better PSES, mainly because they have shown to be intervening factors in variables such as tackling, passes and shots on goal, which are fundamentals for a good performance in futsal, due to the intermediation done by PSES in the connection between MT and other nodes of the network. Nonetheless, it is noteworthy that more experienced athletes feel more effective than younger athletes.

As practical implications, we hope that the present study can be used by sport psychologists and coaches, as well as athletes, as a way of optimizing the processes of training, competitions, and even sport performance. Inducing positive emotions related to great achievements and strategies for coping with failure are important elements in this context. Increasing and enhancing perceptions of PSES and MT are essential to achieve good sport performance, specifically for athletes in team sports such as futsal.

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 Standing Committee on Ethics in Research with Human Beings—Maringá State University (Opinion no 4.022.246). The patients/participants provided their written informed consent to participate in this study.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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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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Modeling the influence of basketball players' offense roles on team performance

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This study aimed to (1) use the clustering method to build a classification model based on the play-type data of basketball players, to classify native and foreign players into different offensive roles; (2) use the clustered offensive role model to investigate how different offensive roles influence team performance. The sample was drawn from 20 teams spanning five seasons (2017–2021) in the Chinese Basketball Association, comprising 823 native and 228 foreign players. The clustering results obtained fourteen offensive roles for native players and five for foreign players. Subsequent analyses revealed that the offensive roles of two native player clusters, namely N6 Spot-up Wings who Attack (OR = 3.281, $p < 0.05$) and N13 Bigs who Cut to the Rim (OR = 4.272, $p < 0.05$), significantly influenced team performance. Conversely, no significant impact was observed for foreign players. The findings of this study offer novel insights into player dynamics and offer coaches a fresh perspective on team composition.

KEYWORDS

team performance, cluster analysis, Chinese Basketball Association, play type, player roles

1. Introduction

The primary objective of sports performance analysis is to enhance the comprehension of sports and consequently guide decision-making processes for individuals aiming to improve their athletic performance (O'donoghue, 2009). Moreover, the dynamic and intricate nature of sports requires a careful analysis through quantitative measurement techniques (Hughes and Franks, 2007). In earlier years, the book 'Moneyball' discussed the use of advanced statistical analysis to evaluate baseball players' performance and worth. This challenged established scouting strategies that typically depend on subjective judgment and outdated data metrics (Lewis, 2004). Previous research has primarily concentrated on retrospective static analyses utilizing historical data and statistical methods to evaluate the performance of individual players or teams (Gomez-Ruano et al., 2020). For instance, distinguishing between winning and losing teams (Gómez et al., 2006; Çene, 2018), elucidating the significance of contributions made by starters and substitutes during games (Gòmez et al., 2009), analyzing variances in physiological indicators among players in distinct positions (Teramoto and Cross, 2018; Zarić et al., 2020), investigating gender disparities (Gómez et al., 2013), and conducting cross-sectional comparisons of performance data across different leagues (Sampaio et al., 2006).

However, over the past decade, researchers have increasingly adopted dynamic and intricate analysis techniques, especially in developing performance models (Gomez-Ruano et al., 2020). These advanced techniques have proven valuable in processing and analyzing the wealth of

available sports data, facilitating the construction of more accurate and reliable performance models (Haghighat et al., 2013). For instance, decision trees have been utilized by researchers to identify patterns in player behavior and performance (Willoughby and Kostuk, 2005; Morgan et al., 2013). Logistic regression has been employed to model the probability of specific game outcomes or player actions (Zdravevski and Kulakov, 2009; Igiri and Nwachukwu, 2014). Support vector machines (SVM) have been used for tasks such as player classification or predicting player attributes (Mustafa et al., 2017; Pai et al., 2017). Random forests have shown promise in capturing complex relationships within sports data and making accurate predictions (Lin et al., 2014; Knoll and Stübinger, 2020). In addition to machine learning models, deep learning approaches, like neural networks, have gained popularity in sports analytics due to their ability to automatically learn and extract intricate patterns from large datasets (Haghighat et al., 2013). These models have demonstrated success in tasks such as player trajectory prediction and play sequence analysis (Kahn, 2003; Ivanković et al., 2010). Moreover, Ranking models, such as Elo Rating, TrueSkill scores, and PageRank algorithms, have been commonly used to assess player or team performance relative to their peers (Barrow et al., 2013; Ibstedt et al., 2019; Kovalchik, 2020). Furthermore, sports research has extensively explored the application of both quantitative and qualitative models. Rule-based models offer interpretability and have been employed to derive decision-making strategies in various sports contexts (Zdravevski and Kulakov, 2009; Trawiński, 2010). Time series models are often used to capture temporal dependencies in sports data, enabling trend analysis and forecasting player performance over time (Yong et al., 2020). Clustering models have been utilized to group players or teams based on similar characteristics, facilitating player profiling and performance comparison (Patel, 2017; Mateus et al., 2020). This combination of analytic techniques, encompassing both quantitative and qualitative variables, provides the foundation of data and information. Importantly, the synergy between these two types of data enables researchers to understand and predict athlete performance more comprehensively, offering valuable insight into the multifaceted drivers of sports performance (O'Donoghue, 2014).

Assessing the critical performance indicators of players and teams is an equally important aspect of sports analysis (Sarlis and Tjortjis, 2020). Previously, basketball data expert Dean Oliver presented a pioneering understanding of data analysis (Oliver, 2004), prompting scholars to subsequently develop diverse metrics for evaluating the game from multiple viewpoints (Cooper et al., 2009; Metulini and Gnecco, 2022). Given that the intricacy of match performance stems from the unique contextual setting in which each match takes place, situational elements like location, opponent, and stage of play exert behavioral influences on the performance of athletes and sports teams (McGarry et al., 2013). Consequently, researchers must pay meticulous attention to the impact of contextual variables when constructing statistical models and investigating critical competition indicators within diverse competitive contexts and conditions, thereby establishing a standardized profile of technical performance during competitions (Hughes et al., 2001; Zhang et al., 2017). Certain studies have consolidated performance indicators across various sports, encompassing game, tactical, technical, and biomechanical indicators on a macro level (Hughes and Bartlett, 2002). Basketball scholars have refined these indicators by introducing Team Performance Indicators (TPI, Yu et al., 2008), which have been instrumental in investigating different facets of basketball.

Basketball is a team sport where success primarily hinges on integrating players with complementary skills (Katzenbach and Smith, 2015). The study of team composition has consistently regarded player positions as a crucial factor, traditionally determined by height and weight considerations (Deman et al., 2001). In particular, taller or more robust players are often stationed near the basket, while smaller players typically exhibit more significant activity on the perimeter (Latin et al., 1994; Ostojic et al., 2006). The conventional approach categorizes players into five positions: Point Guard, Shooting Guard, Small Forward, Power Forward, and Center (Trninić et al., 1999). However, as players develop physically and technically, they can assume multiple roles on the court. Consequently, the traditional method tends to oversimplify the skill sets of high-level players, resulting in suboptimal utilization of team resources (Cheng, 2017). Scholars commonly employ cluster analysis in unsupervised learning to study player positions. Examples encompass hierarchical clustering (Whitehead, 2017a), topology (Alagappan, 2012), K-means and model-based clustering (Kalman and Bosch, 2020), and Gaussian mixture clustering (Wang et al., 2022). Additionally, discriminant analysis (DAs) has demonstrated its suitability for predicting player positions (Pion et al., 2018). However, the studies mentioned above primarily rely on basic statistics, such as box scores, which have inherent limitations (Shea and Baker, 2013). For instance, high scoring can be attributed to a player's shooting technique or the ability of teammates to create favorable shooting opportunities. Similarly, the frequency of defensive rebounds can be influenced by rebounding technique or the number of missed shots by opponents (Remmert, 2003; Christmann et al., 2018). Certain researchers have investigated player behavior by considering interactive information, such as passing and pick-and-roll actions, consistently demonstrating that cooperative play between players yields superior results compared to individual actions (Courel-Ibáñez et al., 2013; Gómez et al., 2015; Marmarinos et al., 2016). Consequently, the study of interactive information data can illuminate the technical and tactical aspects and is more favorable than traditional statistics for analyzing and evaluating athletic performance, as well as assisting coaches in decision-making (Christmann et al., 2018).

Synergy, a sports data science company, offers play-type data and game footage access. They also provide advanced visualization tools for coaches and analysts to analyze opponents' playing styles, monitor player development over time, and gain insights into player and team performance (Božović, 2021; Fu and Stasko, 2022). There are 11 standardized play types in offense, such as spot-up, transition, isolation, off-screen, and so on (Božović, 2021). Basketball offensive tactics are aimed at creating optimal shot selection within a 24-s period. The interplay of gaining separation from the defender(s) (e.g., to shoot or receive a pass) and gaining proximity (for a screen, handoff, cut, or drive) is characteristic of the basketball game (Christmann et al., 2018). These patterns or actions are designed by the coaches, heavily practiced by the players, and then repeated in the game. Understanding how players and teams create successful scoring opportunities is, therefore, critical both practically and theoretically (Matulaitis and Bietkis, 2021). For example, poor pick-and-roll use is recognized as a significant cause of team failure (Vaquera et al., 2013); the most effective finishing moves in the Euroleague are isolation, pick-and-roll, spot-up, and cut (Matulaitis and Bietkis, 2021), while the finishing actions that contribute the least to scoring are off-screen and hand-off (Zukolo et al., 2019). The applicability of these data

TABLE 1 K-means clustering-related play-type indicator.

Play-type	Description
Spot-up	When the possession-ending event is a catch-and-shoot or catch-and-drive play.
Pick-and-roll ball-handler	A screen is set on the ball handler's defender out on the perimeter. The offensive player can use the screen or go away from it, and as long as the play yields a possession-ending event, it is tagged as a pick and roll.
Transition	When the possession-ending event comes before the defense sets following a possession change and a transition from one end of the court to the other.
Cuts	An interior play where the finisher catches a pass while moving toward, parallel to, or slightly away from the basket. This will include the back screen, flash cuts, and times when the player is left open near the basket.
Pick-and-roll man	When a screen is set for the ball handler, the setter receives the ball for a possession-ending event. This action can include: pick and rolls, pick and pops, and the screener slipping the pick.
Post-up	When an offensive player receives the ball with their back to the basket and is less than 15 feet from the rim when the possession-ending event occurs.
Off-screen	Identifies players coming off of screens (typically downs screens) going away from the basket toward the perimeter. This includes curl, fades, and flare.
Putbacks	When the rebounder attempts to score before passing the ball or establishing themselves in another play type.
Isolation	When the possession-ending event is created during a "one-on-one" match-up, the defender needs to be set and have all of his defensive options at the initiation of the play.
Hand-off	The screen setter starts with the ball and hands the ball to a player cutting close by. This enables the player handing the ball off to effectively screen off a defender creating space for the player receiving the ball.
Miscellaneous	When the action does not fit any of the other play types. This includes but is not limited to last-second full-court shots, fouls in the backcourt, and errant passes not out of a different play type.

presents an excellent tool for detailed analysis and creating scout reports (Božović, 2021). Scholars have utilized this data to investigate team styles, player roles, and the influence of various game types on team performance (McBasketball, 2017; Božović, 2021), thereby providing basketball statisticians with a novel perspective for player observation. It is worth noting that player play type is a relatively understudied topic, with minimal research focused on it. Moreover, such studies are particularly scarce for high-level Asian leagues. Therefore, building on prior research, we postulate that classifying players' play-type data will reveal contrasting offensive roles between native and foreign players, which, in turn, will have distinct impacts on team performance.

Given the above considerations, the aims of this study are as follows: (1) use the clustering method to build a classification model based on the play-type data of basketball players, to classify native and foreign players into different offensive roles; (2) use the clustered offensive role model to investigate how different offensive roles influence team performance.

2. Materials and methods

2.1. Sample and variables

The research data was obtained from the sports data website Synergy,[1] and we gained the license to use play-type related data and video. Table 1 presents the category of 11 play types in basketball, these indicators are considered standardized and cover all scoring attempts in the game of basketball, and they were able to translate the team's tactical decisions into countable data (McBasketball, 2017; Božović, 2021). Play-type data was collected for players from 20 teams during five CBA seasons, from 2017 to 2022, encompassing a total of 4,475 games including regular season, playoff qualifying rounds, and playoffs. The raw data consisted of 1,454 native players and 265 foreign players. To ensure the dependability of the clustering and subsequent analysis, players who had less than 3 % of the team's total scoring attempts were excluded. Consequently, our final sample included 823 native players ($n = 823$) and 228 foreign players ($n = 228$).

2.2. Statistical analysis

The initial step involved K-means clustering in categorizing native and foreign players into distinct groups based on their play type data (Zhang et al., 2016; Patel, 2017). The elbow method was employed to determine the optimal number of clusters for the two groups. The clustering results were assessed using the silhouette coefficient (Zhou and Gao, 2014), which ranges between-1 and 1. A higher value closer to 1 indicates superior clustering results, while a negative value indicates poor results. After the clustering results were obtained, the dataset was depersonalized using the t-SNE method, and the results were then visualized (Van der Maaten and Hinton, 2008; Patel, 2017). The process above was implemented using the scikit-learn machine learning framework in Python.

In the second step, non-parametric tests were employed to examine the potential differences in the number of distinct offensive roles between teams that reached the semi-finals and those that did not. Effect sizes (ES) were calculated using Cohen's d, and their

1 https://synergysports.com/sport/basketball/

interpretation followed the established criteria: 0.10 denoted a small effect, 0.30 indicated a medium effect, and 0.50 marked a large effect (Volker, 2006). Additionally, we constructed a logistic regression model to investigate the impact of each offensive role on the team's performance. The number of distinct offensive roles within the team served as the independent variable, while whether the team reached the semi-finals was the dependent variable. Based on their rankings in the season, all teams were categorized as either non-semi-finalists or semi-finalists (code: 0, 1). The threshold for determining statistical significance was set at $\alpha = 0.05$. The above analyses were conducted using IBM SPSS Statistics for Mac, version 24.0 (Armonk, NY: IBM Corp.).

2.3. Reliability and validity of data

To establish the validity of the play type data obtained from Synergy, a random selection of five games per season was observed by three analysts with over 5 years of experience in basketball video analysis. This observed data was then combined with the information provided by Synergy to conduct an intra-group correlation analysis using the Two-Way Mixed-Effects Model (Koo and Li, 2016), ultimately showing a high degree of consistency (ICC = 0.99). The local research institutional review board formally approved all procedures.

3. Results

3.1. Players offensive role definition

Before clustering, the "elbow method" is employed to determine the optimal number of clusters. The primary concept behind this method involves identifying the inflection point where the sum of squared errors (SSE) within a cluster decline significantly. This inflection point represents the optimal number of clusters (Zhang et al., 2016; Cui, 2020). According to Figure 1, the optimal number of clusters for native players is three, while for foreign players, it is two.

Based on the play type percentages depicted in Figure 2, the players can be macroscopically categorized as ball-handlers (C1, C4), wings (C0), and big men (C2, C3) (Whitehead, 2017a; Diambra, 2018). The specific definitions of these three types of roles are as follows:

Ball-Handlers: These roles have a high percentage of pick-and-roll ball-handlers and transition.

Wings: These roles have a high percentage of spot-up and transition.

Big men: These roles have a high percentage of cut, pick-and-roll man, post-up, and putbacks.

Nevertheless, in the context of basketball development, limiting the definition to only three roles deviates from the sport's current developmental trend (Bianchi et al., 2017; Whitehead, 2017a). Consequently, we used K-means clustering to generate fourteen offensive roles (N0-N13) for native players and five (F0-F4) for foreign players. According to Figures 3, 4, the silhouette coefficient calculated for clustering native players is 0.20, indicating a moderate level of both cohesion and separation among the clusters. Put simply, the clusters formed for native players exhibit a certain level of internal similarity while maintaining reasonable distinction from each other. On the other hand, the silhouette coefficient for clustering foreign players is 0.24, indicating an enhanced clustering quality for this group. The clusters formed for foreign players demonstrate improved internal homogeneity and clearer boundaries between them (Zhou and Gao, 2014).

Figure 5 displays the distribution of player clusters based on play type percentages. Similar to other studies that have analyzed player positions and roles using clustering methods, we identify players by observing how they are represented in different types of play data (Lutz, 2012; Wang et al., 2022). The subsequent descriptions outline the offensive roles associated with each offensive role:

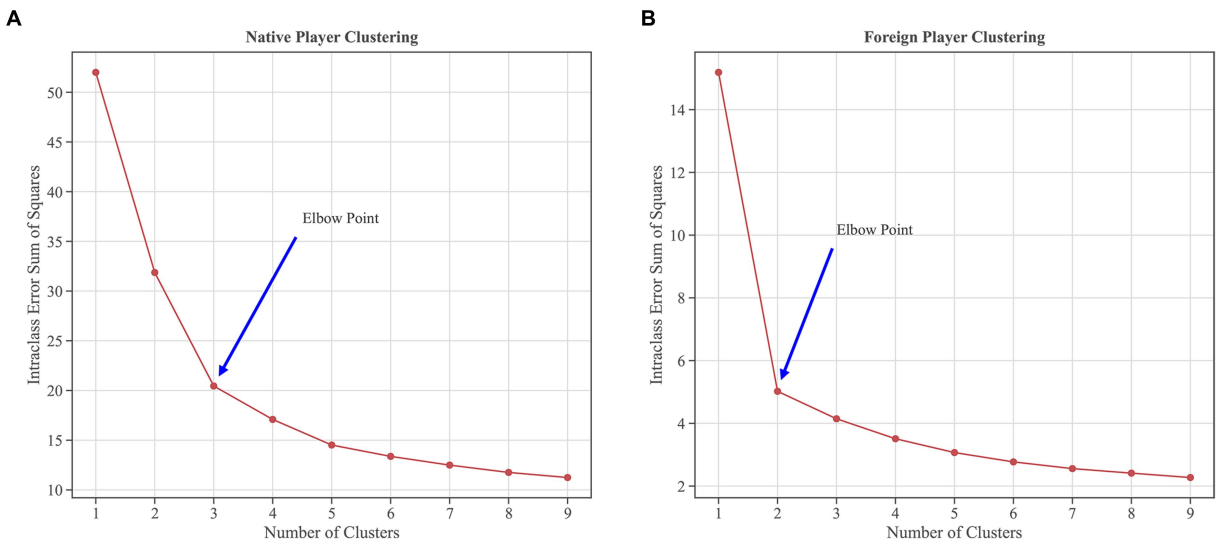

FIGURE 1
The elbow method determines the optimal number of clusters for a player's offensive role. Subfigure **(A)** demonstrates a declining inflection point in SSE for native players when the number of clusters is three; for foreign players, Subfigure **(B)** demonstrates a declining inflection point in SSE when the number of clusters is two.

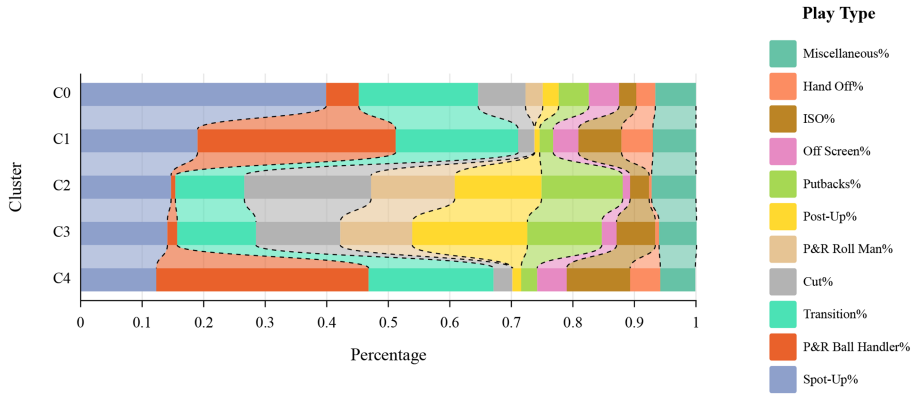

FIGURE 2
Play-type percentage of different clusters (Macro offensive role).

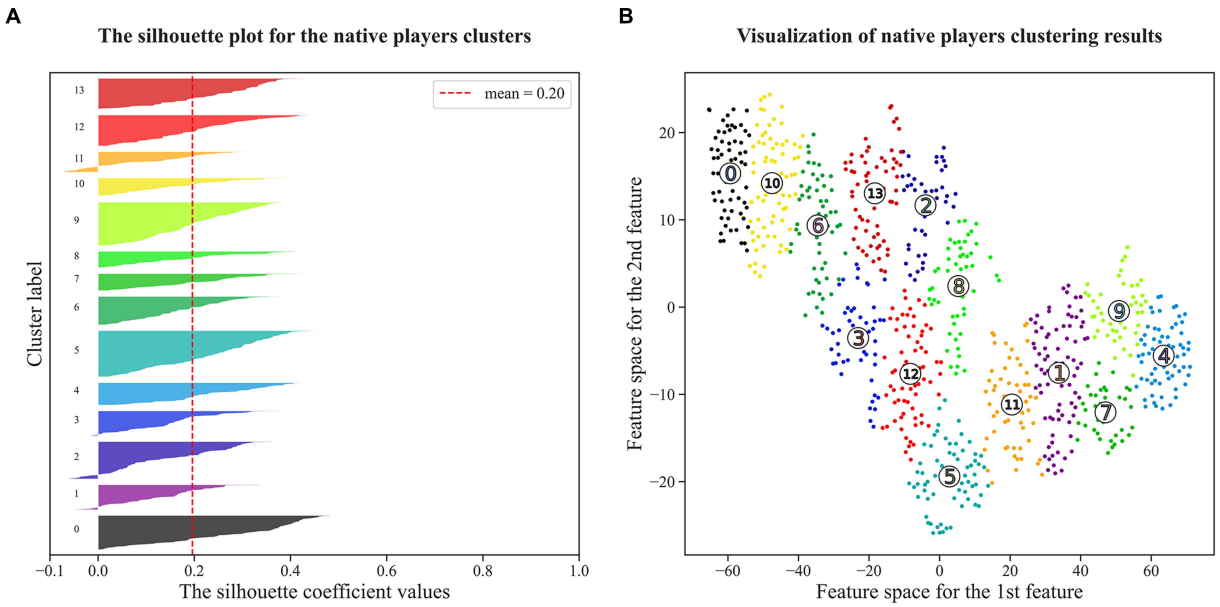

FIGURE 3
Visualization of clustering results for native players. Subplot **(A)** shows that the silhouette coefficients of all clusters exceed the mean value. Subfigure **(B)** transforms eleven play-type variables into two dimensions by the t-SNE dimensionality reduction technique, and the numbers in Subfigure **(B)** correspond to the Cluster Label in Subplot **(A)**.

N0, "Primary Ball Handlers": This group consists of native players with the highest percentage of pick-and-roll ball handlers.

N1, "Mobile Bigs who Cut": This category comprises big men with exceptional mobility and a cutting style of scoring.

N2, "Impact Wings": These players exhibit the highest percentage of participation in transition offenses.

N3, "Stationary Spot-up Wings": This offensive role demonstrates the highest percentage of spot-up plays among all players.

N4, "Stationary Tall Wings": These players exhibit a slightly lower percentage of spot-ups than N3 players but a higher percentage of roll-man plays and putbacks.

N5, "Ball Handlers who Share the Load": This offensive role demonstrates a slightly lower percentage of pick-and-roll ball-handler than the N0 players.

N6, "Spot-up Wings who Attack": These players possess a high spot-up percentage but primarily rely on cuts, roll-man, and putbacks to score.

N7, "Bigs who Roll to the Rim": These players play a significant role in the pick-and-roll offense, frequently rolling to the basket to score after setting a screen.

N8, "Mobile Bigs who Post-up at the Rim": These players exhibit the highest post-up percentage among native players and actively contribute to pick-and-roll plays and cuts for scoring opportunities.

N9, "Spot-up Wings who Transition": This offensive role predominantly engages in spot-up and transition plays, while other play types are less prevalent.

N10, "Tall Wings who Pick-and-pop": These players are characterized by a high spot-up and roll-man percentage, indicating their inclination toward catch-and-shoot plays following a pick.

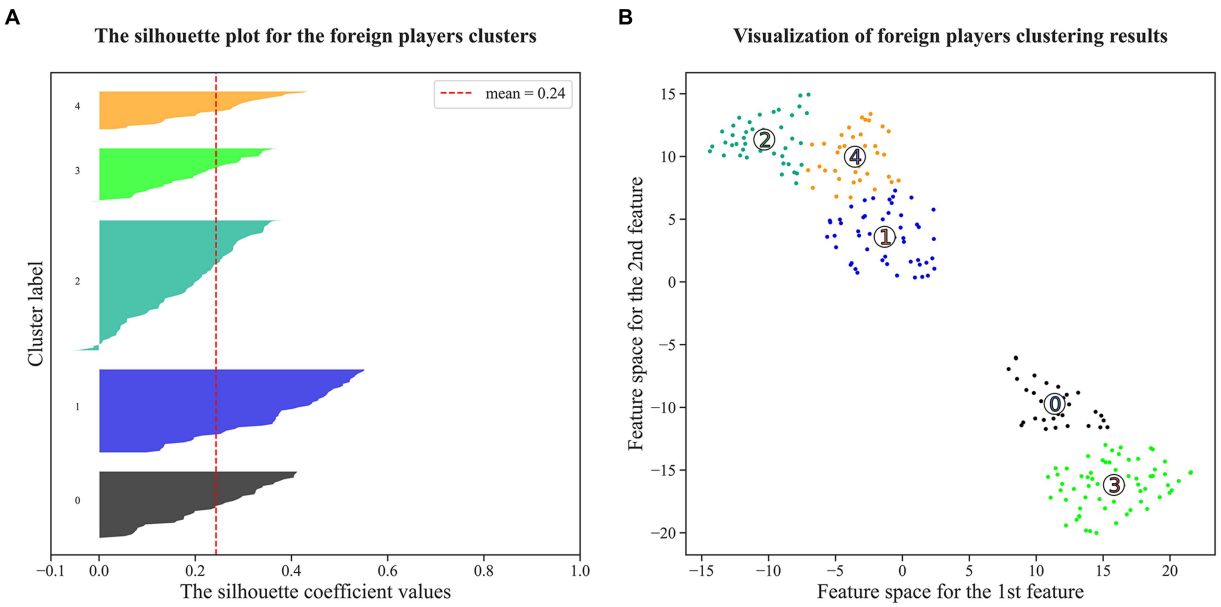

FIGURE 4
Visualization of clustering results for foreign players. Subplot **(A)** shows that the silhouette coefficients of all clusters exceed the mean value. Subfigure **(B)** transforms eleven play-type variables into two dimensions by the t-SNE dimensionality reduction technique, and the numbers in Subfigure **(B)** correspond to the Cluster Label in Subplot **(A)**.

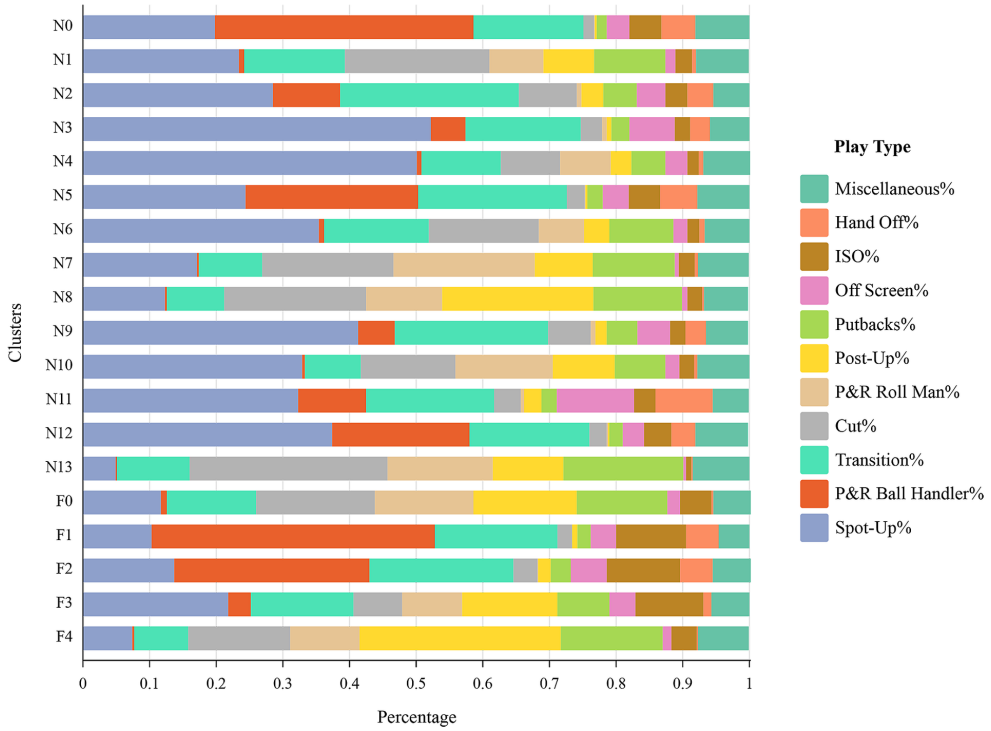

FIGURE 5
Play-type percentage of different clusters (Specific Offensive roles).

N11, "Wings who Work Around Screen": This offensive role excels at scoring by utilizing screens set by teammates on the court, leading to a high off-screen and handoff percentage.

N12, "Ball-handler with Off-ball Duties": This offensive role exhibits a lower pick-and-roll ball-handler rate than N0 and N5 players but demonstrates a higher spot-up percentage.

TABLE 2 Non-parametric test of the number of different offensive roles.

Clusters	Whether to reach the semi-finals(M±SD)		Mann–Whitney U	Mann–Whitney z	*p*	ES
	No (*n* = 79)	Yes (*n* = 20)				
N0	0.68±0.96	0.85±1.04	724	−0.635	0.525	0.17
N1	0.51±0.64	0.60±0.68	731	−0.582	0.56	0.14
N2	0.75±0.91	0.90±1.17	760	−0.284	0.776	0.15
N3	0.51±0.71	0.60±0.75	735.5	−0.544	0.586	0.13
N4	0.48±0.68	0.45±0.51	770.5	−0.197	0.844	0.05
N5	1.00±0.97	0.80±0.62	733	−0.528	0.597	0.25
N6	0.58±0.79	0.65±0.49	675	−1.122	0.262	0.10
N7	0.35±0.64	0.40±0.50	712	−0.853	0.394	0.08
N8	0.37±0.70	0.30±0.47	788	−0.022	0.982	0.11
N9	0.87±0.76	1.00±0.80	727.5	−0.59	0.555	0.16
N10	0.49±0.83	0.00±0.00	520	−3.017	0.003**	0.84
N11	0.49±0.68	0.20±0.41	616	−1.794	0.073	0.53
N12	0.63±0.85	0.70±0.57	682.5	−1.038	0.299	0.09
N13	0.54±0.68	1.05±0.95	552	−2.286	0.022*	0.62
F0	0.42±0.52	0.40±0.60	759	−0.317	0.751	0.03
F1	0.51±0.60	0.55±0.69	776.5	−0.134	0.894	0.07
F2	0.79±0.81	0.85±0.75	735	−0.518	0.604	0.08
F3	0.34±0.53	0.30±0.57	745	−0.49	0.624	0.08
F4	0.29±0.46	0.05±0.22	599.5	−2.237	0.025*	0.67

*Means $p < 0.05$, **means $p < 0.001$, ES, Effect Size.

N13, "Bigs who Cut to the Rim": These players exhibit the highest percentage of cuts and putbacks while displaying the lowest percentage of spot-up plays.

F0, "Bigs with Skills Everywhere": These skilled bigs employ a diverse array of plays to attempt scoring, including posting up inside, spotting up outside, and executing cuts or rolls to the basket.

F1, "Domineering Ball Handlers": These players possess the highest percentage of pick-and-roll ball handlers and exhibit much isolation plays.

F2, "Wings who Initiate Offense": These players demonstrate a particular percentage of pick-and-roll ball-handling and isolation plays. Despite not being the primary ball handlers on the court, they can initiate attacks with the ball.

F3, "Ball Stopping Mobile Bigs": This offensive role is distinguished by a high percentage of spot-ups and isolation plays, often resulting in individual finishes for possessions.

F4, "Bigs with Skills in the Post": This offensive role demonstrates the highest post-up percentage, indicating a greater emphasis on low-post offense.

3.2. Analysis of the influence of offensive roles on team performance

We initially examined if there existed differences in the diversity of offensive roles within the teams. Non-parametric test results (Table 2) indicate that categories N10 Tall Wings who Pick-and-pop ($p < 0.01$, ES = 0.84), N13 Bigs who Cut to the Rim ($p < 0.05$, ES = 0.62), and F4 Bigs with Skills in the Post ($p < 0.05$, ES = 0.67) exhibited significant disparities among the teams that advanced to the semi-finals and those that did not.

Further, we constructed a logistic regression model using the number of offensive roles and the team's performance. Table 3 displays the logistic regression model's indicators. For native players, significantly positive effects were observed for N6 Spot-up Wings who Attack (OR = 3.281, $p < 0.05$) and N13 Bigs who Cut to the Rim (OR = 4.272, $p < 0.05$). The offensive roles of foreign players did not significantly impact the team's quality.

4. Discussion

The aim of this study was to (1) use the clustering method to build a classification model based on the play-type data of basketball players, to classify native and foreign players into different offensive roles; (2) employ the classified offensive role model to examine the impact of diverse offensive roles on team performance.

Performance modeling is a valuable tool with diverse applications, including predicting game results (Zdravevski and Kulakov, 2009), identifying tactical strategies (Tian et al., 2019), aiding in player draft and recruitment processes (Berri et al., 2011), and evaluating player and team performance (Terner and Franks, 2021). Several studies have utilized this approach to categorize players' positions and roles and forecast their performance (Rangel et al., 2019; Wang et al., 2022). However, comparative studies between native and foreign players have

TABLE 3 Logistic regression analysis of players' offensive roles.

Clusters	β	SE	z score	Wald χ^2	p	Odds ratio	CI 95%
N0	−0.123	0.403	−0.305	0.093	0.761	0.884	0.401 ~ 1.950
N1	0.92	0.673	1.367	1.869	0.172	2.509	0.671 ~ 9.381
N2	0.248	0.423	0.586	0.343	0.558	1.281	0.559 ~ 2.934
N3	−0.255	0.659	−0.388	0.15	0.698	0.775	0.213 ~ 2.817
N4	0.399	0.721	0.553	0.306	0.58	1.49	0.363 ~ 6.125
N5	−0.576	0.511	−1.127	1.27	0.26	0.562	0.207 ~ 1.531
N6	1.188	0.586	2.029	4.116	0.042*	3.281	1.041 ~ 10.342
N7	0.985	0.816	1.207	1.457	0.227	2.678	0.541 ~ 13.259
N8	1.026	0.969	1.058	1.12	0.29	2.789	0.417 ~ 18.635
N9	0.39	0.555	0.703	0.494	0.482	1.477	0.497 ~ 4.389
N10	−1.675	0.579	−1.957	3.571	0.997	0.383	0.027 ~ l.272
N11	−1.416	0.945	−1.498	2.244	0.134	0.243	0.038 ~ 1.547
N12	−0.009	0.558	−0.016	0.075	0.987	0.991	0.332 ~ 2.960
N13	1.452	0.629	2.31	5.335	0.021*	4.272	1.246 ~ 14.649
F0	−0.002	0.75	−0.002	0.068	0.998	0.998	0.229 ~ 4.344
F1	0.669	0.782	0.855	0.731	0.393	1.952	0.421 ~ 9.044
F2	0.3	0.578	0.518	0.269	0.604	1.35	0.434 ~ 4.194
F3	0.315	0.803	0.393	0.154	0.695	1.371	0.284 ~ 6.610
F4	−2.008	1.285	−1.562	2.439	0.118	0.134	0.011 ~ 1.668

Nagelkerke $R^2 = 0.468$, β, Regression Coefficient; SE, Standard Error. *means $p < 0.05$.

rarely employed similar approaches. Most studies have consistently demonstrated the superior capabilities of foreign players compared to native players, suggesting their need for a more significant on-court role (Guimarãe et al., 2018; Gasperi et al., 2020). Performance modeling helps mitigate these biases and preconceptions, enabling a fair and data-driven assessment of players from different backgrounds. This is especially crucial for foreign players, as their style and skill sets may differ from native players due to cultural, training, and developmental factors (Ozmen, 2012). Nevertheless, it is essential to recognize the limitations of performance modeling. The reliability of predictions can be influenced by the quality, completeness, and accuracy of the data on which the models rely (Fu and Stasko, 2022). Additionally, basketball is a complex and dynamic game influenced by various situational factors, teamwork, and coaching strategies, which the models may not fully capture. Caution should be exercised by coaches and researchers when interpreting and relying solely on predictions generated by performance modeling, acknowledging the critical role of human judgment and expertise in the decision-making process (Remmert, 2003; Lamas et al., 2015).

To accurately reflect the contemporary dynamics of the sport, it is necessary to reassess the categorization of player roles in modern basketball. Conventional classifications, including point guard, shooting guard, small forward, power forward, and center, no longer encompass versatility and blurred positional boundaries (Latin et al., 1994; Ostojic et al., 2006). Contemporary players possess a broader spectrum of skills and physical conditioning, allowing them to assume multiple roles on the court. This transformation is propelled by the emphasis on versatility, floor spacing, and the ability to create mismatches (Bianchi et al., 2017; Whitehead, 2017b). In their study of the Brazilian professional basketball league, Rangel et al. noted that versatility players showed an upward trend over nine seasons and presented a higher frequency at the power forward and point guard positions (Rangel et al., 2019). Trninić et al. proposed multidimensional criteria for the various positions and roles of the game of basketball, and their findings showed that the ability to play multiple positions is crucial for players at positions 2 and 3, while players at position 1 are more expert players (Trninić et al., 2000). In basketball, certain guards assume the role of ball handlers within their team, which forwards or centers may also take on. Conversely, some guards do not fulfill the ball handler role, and this principle can be extended to other positions on the court (Sailofsky, 2018). This coincides with our findings: our clustering results yielded 8 categories of wings and 7 categories of big men, reflecting the importance of forward players playing multiple roles in the game; there were only 4 categories of ball-handlers, suggesting that combing the offense and creating scoring chances are their main responsibilities. In addition, the study by Rangel et al. noted that the roles of foreign players showed higher diversity (Rangel et al., 2019). In our study, except for F1 players who are required to be the team's primary ball-handler, the other types of players showed diversity in their scoring styles. Although the diversity of player roles is a growing trend in basketball, having more than three such "glue guys" proved to be detrimental to team performance in the study by Lutz (2012). Therefore, coaches should try to balance the playing positions and tactical roles of players when constructing lineups.

Our study employed the elbow method to categorize players into three macro-level roles: ball handlers, wings, and big men. Previous studies have reported similar findings, corroborating and reinforcing our findings (Bianchi et al., 2017; Whitehead, 2017a). These findings offer valuable insights for analyzing player roles and conducting further research on the evolution of basketball tactics. Subsequent categorization

revealed 14 offensive roles for native players and five for international players. Several previous studies have also created specific labels for basketball players' roles in the game. For example, Alagappan et al. expanded the traditional five positions to 13 (Alagappan, 2012), and Lutz et al. defined players into 10 different clusters (Lutz, 2012). This categorization, however, fails to fully transcend the conventional positional constraints due to the substantial variation in statistical metrics across different player positions. For instance, guards tend to have higher counts of assists and successful three-point shots, whereas centers excel in rebounds (Sampaio et al., 2006). There are also clusters of a few players, such as "one-of-a-kind," which are individuals with outstanding talent and statistics, For example, James Harden and Russell Westbrook, who perform well in a variety of statistical data (Alagappan, 2012; Lutz, 2012). While these players are not necessarily guaranteed to win (Lutz, 2012), they are key players that every team pursues. Stated differently, these player clusters might lack representativeness as not all teams can boast of having such players. Consequently, the delineation of players according to roles, rather than rigid positions, facilitates adaptability and flexibility in response to team strategies and individual proficiencies (Lorenzo et al., 2019; Zhang et al., 2019). In the course of a game, adept teams swiftly modify their successive offensive maneuvers in response to varying defensive shifts, whereas alterations in defensive strategies minimally affect offensive actions (Christmann et al., 2018). Hence, characterizing player roles through play-type data will better mirror a player's skill set and designated role.

An analysis of the offensive role composition in different teams demonstrated significant variations among three distinct offensive role categories, all falling within the classification of big players (N10, N13, F4). Prior studies on player classification consistently demonstrate the relatively low number of big men. Furthermore, the rarity of big men with specific skills like long-range shooting or proficiency in the low post hampers their availability on most teams (Çene, 2018). Consequently, teams without such players must adjust their tactics or select alternative types of big men as substitutes (Wang et al., 2022). The logistic regression results revealed a positive impact of the two offensive roles (N6 and N13) on a team's advancement to the semi-finals. Consistent with previous studies on play types, successful teams were found to exhibit more cuts, low-post offense, spot-up shots, and free throws (Zukolo et al., 2019; Matulaitis and Bietkis, 2021), which aligns with the characteristics of the two identified offensive roles. Furthermore, the significance of the off-ball movement was emphasized. Additionally, offensive rebounding emerged as a crucial aspect of performance. Offensive rebounding creates secondary scoring opportunities and diminishes the opponent's chances of transitioning into offense (Zukolo et al., 2019). Ball handlers play a pivotal role within the team, as over half of the set-offense are initiated through ball screens (Gómez et al., 2015; Vaquera et al., 2016). However, research has indicated that lineups with more than two high-usage ball handlers tend to underperform, decreasing team efficiency (Kalman and Bosch, 2020; Wang et al., 2022). The same finding was also seen in the study by Lutz et al. who noted that ball handlers have a negative impact on a team's point differential (Lutz, 2012). Transition offense, while efficient, does not exhibit significant correlations with game outcomes, likely due to its relatively small proportion within overall gameplay (Selmanovi, 2015; Suárez-Cadenas et al., 2016; Matulaitis and Bietkis, 2021). Consequently, players specializing solely in transition offense and spot-up shooting are considered highly interchangeable. Moreover, players proficient in scoring from screens (N11) heavily rely on the team's ability to create space for them and face heightened defensive pressure (McIntyre et al., 2016). Notably, off-ball screens and hand-offs contribute the least to scoring; losing teams tend to have more attacks (Suárez-Cadenas et al., 2016; Zukolo et al., 2019).

Finally, our study indicates that the offensive role of foreign players has no substantial impact on team performance. These findings align with prior research that found no significant difference in efficiency between foreign players of top teams and average (non-top) teams (Ozmen, 2012; Wang et al., 2022). Conversely, native players of top teams are more efficient than native players of teams outside the top tier. Native players in the CBA league exhibit distinct offensive characteristics, with spot-up, transition, and cutting actions comprising a significant portion of their gameplay. These offensive strategies prioritize teamwork and have been proven effective in several studies (Christmann et al., 2018; Zukolo et al., 2019; Matulaitis and Bietkis, 2021). However, they rely on teammate support for execution, making these offensive roles often perceived as scoring beneficiaries (Whitehead, 2017b; Zukolo et al., 2019). In contrast, pick-and-roll ball handlers, isolation, and post-ups were more prevalent among foreign players. While some studies disagree on the efficiency of these playing styles (Selmanovi, 2015; Christmann et al., 2018; Zukolo et al., 2019), they tend to emphasize individual ability. Consequently, these offensive roles are regarded as scoring creators (Whitehead, 2017b; Zukolo et al., 2019), particularly in teams lacking strong scoring capabilities, where the role of these players becomes even more vital (Arcidiacono et al., 2017). Conversely, foreign players have demonstrated superior talent to domestic players in the league (Ozmen, 2012; Özmen, 2019; Gasperi et al., 2020). Due to the distinct playing time regulations concerning foreign players in the CBA league, teams are constrained to field a single foreign player during each quarter. This stipulation has led most teams to prioritize the scoring ability of these foreign recruits. Lutz et al. pointed out in their study that some player classifications such as aggressive bigs, big bodies, and perimeter scorers, have a negative impact on the game score difference (Lutz, 2012). Also, it was mentioned in their study that big players are generally unfavorable to the outcome of the game (Lutz, 2012), which diverges from our findings. Our explanation is that similar to the roles of native and foreign players in other leagues, native players play a secondary role in their team's offense, relying on their teammates to create chances while focusing more on defense and other secondary responsibilities and playing a lesser role in the creative aspects of the game (Guimarãe et al., 2018; Özmen, 2019); while some studies have also pointed out that big players who focus on defense have a positive impact on the outcome of the game (Lutz, 2012; Wang et al., 2022), which support our research findings. These insights prompt coaches to recognize that with all teams having the funds to recruit talented foreign players, it is vital to develop native players, especially big men with a great sense of teamwork and defensive ability.

5. Limitations and future directions

This study has certain limitations. Firstly, similar to other studies employing clustering for player role classification, the final clustering results are inherently subjective, leading to the possibility of misclassifying players into different roles, which is an unavoidable issue in clustering studies. Secondly, basketball is a multifaceted game with various dimensions, where player roles can significantly fluctuate depending on team strategies, game situations, and opponent

circumstances. This study solely analyzed players' offensive types while neglecting relevant defensive metrics. Some players renowned for their defensive prowess may have been overlooked, potentially oversimplifying players' roles and disregarding the diversity of their on-court contributions. Lastly, when studying the impact of offensive roles on team performance, we solely employed the number of players as the independent variable due to sample size limitations; other variables were not considered, such as players' playing time and efficiency values across different play types, which constrained our ability to investigate further the influence of players' roles on team performance.

Regarding future research directions, several areas warrant exploration. First, player roles evolve in response to coaching decisions, formation adjustments, and player development. Investigating the patterns and trends of these role changes is one of the areas we intend to explore. Second, incorporating a larger sample size and additional influential variables concerning the impact of player roles on team performance would enhance model stability, thereby facilitating the further investigation of the matter. Lastly, future research should integrate advanced machine learning techniques like deep or reinforcement learning to capture player roles' intricate relationships and temporal dynamics. These approaches are adept at handling large-scale data, identifying complex patterns and dependencies, and yielding a more nuanced comprehension of offensive roles.

6. Conclusion

In this study, we utilize play-type data with interaction information to categorize native and foreign players in the CBA league into 14 and five distinct offensive roles, respectively, employing a clustering approach. These results provide a unique perspective for understanding and observing the player's role. Further research found that big players made a difference in team composition. The offensive roles of two categories of native players, whose attributes emphasized both teamwork and off-ball movement, showed a significant influence on team performance. In contrast, no such impact was found for foreign players. Consequently, basketball coaches and managers should consider optimizing the composition of individual player clusters during the team-building process and prioritize the development of native players.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants or patients/participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

RC: Data curation, Software, Visualization, Writing – original draft. MZ: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. XX: Methodology, Software, Writing – review & editing.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1256796/full#supplementary-material

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Impact of the number of players on the emergence of creative movements in small-sided soccer games: a systematic review emphasizing deliberate practice

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Introduction: Creativity is a recognized quality in various areas, including sports. Within the training processes, various modifications to objectives, game configurations, rules, among other factors, can be considered to favor creative solutions to the tactical problems inherent to soccer. This systematic review aimed to identify the impact of the number of players on the emergence of creative movements in small-sided soccer games, emphasizing deliberate practice.

Methods: A systematic review of Scopus, PubMed, Scielo, PsycInfo, SportDiscus and Lilacs databases was performed according to PRISMA guidelines. Eligibility criteria were defined based on the elements of population, context and concept. Only full articles published in scientific journals written in English were included. No period restriction was applied.

Results: Five papers were included and the results of studies indicate greater number of actions, variability, and creativity in small-sided games compared to formal soccer matches. When comparing different small-sided game formats, 5 v 5 showed higher values in terms of total number of actions compared to 7 v 7, and the absolute number of original and creative actions tended to decrease as the game format increased. Imbalanced small-sided games format can promote increased exploratory behavior. Structural manipulation in goal positioning in 5 v 5 games may also influence the originality of tactical behaviors, while the use of different ball types in 4 v 4 games appears to decrease fluency values. In 6 v 6 games, fluency and versatility are negatively impacted.

Conclusion: Reduced game formats with fewer players and in smaller field dimensions provide more suggestive environment for exploratory behavior, variability and original and creative actions. The protocol was registered on the Open Science Framework (OSF) on 2 December 2022 (DOI: 10.17605/OSF.IO/VN6YZ).

Systematic review registration: [https://osf.io/jmf4k/].

KEYWORDS

divergent thinking, creativity, game format, tactical creativity, exploratory behavior

1. Introduction

Creativity is a quality required in various areas of expertise. Nevertheless, studies on creativity received greater attention only after Joy Paul Guilford's historic speech upon assuming the presidency of the American Psychological Association (APA) in 1950 (De Sa Fardilha and Allen, 2019). In this speech and in his manuscripts, the president of APA pointed out the negligence of studies in the psychology field regarding the subject of creativity, as well as the importance of studying it rigorously and systematically (Guilford, 1950). From then on, creativity began to be understood as the manifestation of new and original ideas that are at the same time useful and designed for problem solving (Guilford, 1956; Sternberg and Lubart, 1999).

The "Guilfordian" view of the phenomenon proposes four theoretical constructs for recognizing creativity, namely fluency, flexibility, originality, and elaboration. Fluency refers to the generation of large number of ideas and responses in a short period of time; flexibility concerns the ability to think in different categories or perspectives, switching from one class of ideas to another; originality consists of the unique or rare quality of ideas; while elaboration involves expanding and coherently detailing the generated ideas (Furley and Memmert, 2018; Büning et al., 2020).

Advances in studies based on cognitive approaches to creativity have contributed to a paradigm shift and consequent shift away from innatist theories that have long supported discussions in this area (Ritter and Mostert, 2017). From then on, new theoretical perspectives have been considered. Amabile (1983) highlighted the importance of understanding social and motivational aspects beyond cognitive ones. In line with this, Glăveanu (2010) also attributes creativity to cultural and social factors, taking into account the available affordances in the context of action, i.e., social and cultural possibilities for an action to occur. Sharing a view that transcends the individual and isolated analysis of creative action, Csikszentmihalyi (1999) changes the origin focus of creation, shifting the genesis of the creative process from the psychological sphere and arguing that personal factors such as personality, intrinsic motivation, and values, while important, are not sufficient to explain creativity. By considering creativity as a process that emerges from interactions between the person, the symbol system, and the social organization of domain, Csikszentmihalyi presents a systemic model of creativity, in which the creative process is characterized by symbolic changes operationalized by individuals, embedded in a social domain, and with the participation of the field of expertise that validates and introduces innovations into society.

With the advancement of theoretical models capable of explaining the creative phenomenon, researchers in sports pedagogy have found scientific support to help them understand how the teaching and training processes of sports can contribute for the production of surprising, original, and flexible tactical-technical responses for a given game situation (Roth, 2005; Memmert and Roth, 2007). The Tactical Creativity Approach (TCA) model presents the 6 D's to foster tactical creativity, which are: Deliberate Play, 1-Dimension Games, Diversification, Deliberate Coaching, Deliberate Motivation, and Deliberate Practice (Memmert, 2015). Although still incipient, some findings in literature suggest that deliberate play, free, informal, and unstructured game situations seem to favor the development of creativity in young players (Memmert et al., 2010; Roca and Ford, 2021).

In addition to the cognitive perspective of understanding the phenomenon, researchers have brought the understanding of creativity closer to the ecological approach, which consider the importance of the set of tasks, personal and environmental memories and also their interaction on the action system. In this sense, greater contextual variability and freedom of exploration increase the emergence of new, adaptive and functional solutions (Hristovski et al., 2011; Orth et al., 2017).

In soccer, the development of tactical-technical content and creativity through games can occur by manipulating the structural and/or functional rules of small-sided games (Santos et al., 2016; Duncan et al., 2022). In this sense, a study conducted by Santos et al. (2018) found that a training program with small-sided games, based on a wide range of modifications to objectives, game configurations, rules, and other factors has the potential to develop creativity in soccer, corroborating the findings of Coutinho et al. (2018), who found improvements after a training program based on differential learning for physical performance, technical variables and creative components. As previously seen, variability is an important indicator for exploration and functional solutions, Caso and van der Kamp (2020) compared different of small-sided game formats and concluded that the fewer players, the more (creative) actions they perform, finding that action variability in settings with fewer players may favor action originality.

Clemente and Sarmento (2020) demonstrated that small-sided games can be used to develop technical actions and skills in soccer. Another study showed that variations in games lead to different tactical behaviors (Clemente et al., 2021). However, no systematic review has sought to understand how the possible manipulations in small-sided games lead to the emergence of creative actions in soccer. Considering the importance of summarizing scientific evidence about small-sided game formats that favor creative actions in the teaching and training environment of soccer, the purpose of this systematic review was to understand the impact of the number of players and field dimensions on the emergence of creative movements in small-sided soccer games. The initial hypothesis of this investigation is that smaller game formats, with fewer participants, reduce the possibilities of interactions between teammates for problem-solving, increasing exploratory behaviors in the playing space that enable the emergence of new, original, useful and problem-oriented actions. The identification of which contexts favor the emergence of creative actions can provide coaches with insights to design training formats that generate environments with greater potential for creativity development. This quality, highly valued in the performance of soccer players, is found in admired and idolized athletes, such as Lionel Messi, whose skills have the potential to foster and influence the emergence of new creative players (Furley and Memmert, 2018).

2. Methods

2.1. Protocol and registration

The protocol and development of the systematic review followed the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015 (Moher et al., 2015), composed of a 17-item checklist intended to facilitate the preparation and reporting of the systematic review. The protocol was registered on the Open Science Framework (OSF) on 2 December 2022 (DOI: 10.17605/OSF.IO/VN6YZ).

2.2. Eligibility criteria

The eligibility criteria were defined based on the PCC mnemonic Population, Context, and Concept suggested by the Joanna Briggs Institute (Peters et al., 2015).

(I) Population: soccer players, without restrictions on age, sex, nationality, competitive level and practice time, aiming for greater coverage of the emerging theme.
(II) Context: small-sided games in soccer, covering all protocols that include the use of small-sided games, even if they involve other manipulations of task constraints in addition to the numerical configurations of the matches.
(III) Concept: assessment of creativity in soccer, bringing measures that can quantify the manifestation of creative movements in a clear and objective way.

At the time of the search, there was no restriction on the interval in years. Only full articles published in scientific journals written in English were included. For exclusion, some criteria were adopted based on PICOS (Methley et al., 2014).

(I) Population: not applicable. No criteria of exclusion were established for the population so as not to conflict with the eligibility criteria.
(II) Intervention: studies that evaluate creativity in small-sided games in other sports or those that are not related to small-sided soccer games, removing studies that involve small-sided games in sports other than soccer, as well as studies in soccer that use evaluation methods other than small-sided games.
(III) Comparison/Control: not applicable.
(IV) Outcome measure(s): studies in which the outcome is not related to the sports context or studies that did not present creativity measure, excluding studies that mentioned creativity without relating it to measures that allow clear and objective quantification.
(V) Types of studies: abstracts, thesis and dissertations, and qualitative studies.

2.3. Information sources and search strategy

The search was conducted from December 3 to 7, 2022, in electronic databases (Scopus, PubMed, Scielo, PsycInfo, SportDiscus, and Lilacs). This group of databases was chosen due to their relationship with the study theme and because the group includes bases used worldwide in review studies. The gray literature was not accessed in order not to contradict the exclusion criteria related with type of studies, and the additional search was performed through hand searches of reference list from included studies and email contact with experts. The keywords and Boolean operators for the search were: 'creativity' OR 'intelligence' AND 'small-sided games' OR 'conditioned games' OR 'deliberate play' OR 'deliberate practice' AND 'soccer'.

2.4. Data management

The search results were exported from database websites such as 'RIS' files, a data exchange format used by a variety of reference managers, and inserted into the Covidence software for managing and streamlining systematic reviews.

2.5. Selection and data collection process

The systematic review selection process was presented in accordance with the PRISMA 2020 Flow Diagram for New Systematic Reviews proposed by Page et al. (2021). The process started with the identification, in which studies were found through the search strategy in databases and registers. Reports of selected data were generated using the Covidence reference manager software, the tool being applied so that reviewers could extract data independently and facilitating data export. Also, the tool was used to remove duplicate records before the screening phase. The study selection process was carried out by two independent reviewers. Reviewers 1 and 2 performed a calibration exercise before starting the independent analysis of screened records, whose task consisted of independently reading the titles and abstracts of 10 articles and subsequent discussion.

The first step of the screening phase consisted of reading the titles and abstracts of all articles found based on established search strategy in selected databases and that passed the duplicate filter. Subsequently, the two reviewers evaluated the articles with the intention of including them for the next stage or discarding them, respecting the eligibility criteria. After this process, the reviewers analyzed the disagreements and try to reach consensus. In cases where consensus was not possible, reviewer 3 was available to assist in the decision and made the final decision. Once again, a calibration was performed between reviewers 1 and 2, this time based on the reading, checking and discussion of three complete articles. The second step of the screening phase was operationally similar to the previous step. However, this time reviewers will read the articles that reached this stage in full and again differences were solved by reviewer 3.

Subsequently, the additional search step was performed in two ways. The first in the list of bibliographic references used in the included studies, to find possible studies that were not identified in the initial search. The second way, through email contact with the main authors in the area.

Finally, the reviewers met once again to seek a consensus and definition of selected articles. In this final stage of the selection process, only studies included in the review remained.

2.6. Data items

For the current study, fluency, originality and flexibility measures were selected as the main outcomes. These variables were chosen because they are often used to operationalize tactical creativity, identified by mean of factor analysis (Guilford, 1967). In this sense, originality is understood from the exceptionality of tactical solutions and can be rated by experts, flexibility encompasses the variety of tactical solutions, being determined by the diversity of actions/responses of test participants, and fluency concerns the number of tactical solutions that the individual generates for a specific situation of the match (Memmert, 2015). Exploratory behavior was also defined as an outcome measure, being understood as the "subsequent performance of a large number of movement configurations that reveal the hierarchical action landscape under specific constraints of each performer" (Hristovski et al., 2011, p. 187) or team.

2.7. Outcomes and prioritization

All included studies used more than one small-sided game format; however, only one analyzed the isolated impact of the balanced number of players and pitch size on creativity. Four other studies presented small-sided game structures, but also performed other manipulations. Two studies proposed imbalanced games, in which the number of players from the teams were different (Torrents et al., 2016; Canton et al., 2019). One of studies added the change in the positioning of goals (Canton et al., 2020) while another used different types of ball in games (Santos et al., 2020). Thus, in addition to the main outcomes related to the impact of pitch size and number of players on creativity measures, results related to other types of structural manipulations were also identified.

2.8. Risk of bias in individual studies

The Joanna Briggs Institute Critical Appraisal tools (JBI) for use in systematic reviews of cross-sectional studies (Moola et al., 2020) was used (Table 1). As recommended by PRISMA (Moher et al., 2015), two reviewers independently assessed each study based on the criteria used to rank risk of bias. Disagreements were resolved by consensus between reviewers 1 and 2, and consultation with a third reviewer was not necessary. The instrument consists of the following questions: "Were the inclusion criteria in the sample clearly defined?"; "Were the study subjects and the setting described in detail?"; "Was the exposure measured in a valid and reliable way?"; "Were standard criteria used for condition measurement objective?"; "Were confounding factors identified?"; "Were strategies to deal with confounding factors stated?"; "Were the outcomes measured in a valid and reliable way?"; "Was appropriate statistical analysis used?." To classify questions, they were flagged as "yes," "no," "unclear" or "not applicable."

2.9. Confidence in the cumulative evidence

The assessment of confidence in the cumulative evidence was also carried out by two independent reviewers in order of verifying the strength of the body of evidence so that any disagreements are resolved through a consensus meeting or with the help of an expert.

The modified version of the Quality Index (Downs and Black, 1998) adopted in recent systematic reviews (Bujalance-Moreno et al., 2019; Praça et al., 2022) was used to assess the methodological quality of eligible studies. The original scale is composed of 27 items, of which only 14 were verified in studies, since the other criteria were considered not applicable to studies of this review. The tool modification resulted in the following criteria: (1) Is the hypothesis/aim/objective of the study clearly described?; (2) Are the main outcomes to be measured clearly described in the Introduction or Methods section?; (3) Are the characteristics of participants included in the study clearly described?; (6) Are the main findings of the study clearly described?; (7) Does the study provide estimates of the random data variability for the main outcomes; (10) Have current probability values been reported (e.g., 0.035 rather than <0.05) for the main outcomes except where the probability value was less than 0.001?; (11) Were subjects asked to participate in the study representative of the entire population from which they were recruited?; (12) Were subjects who were prepared to participate representative of the entire population from which were they recruited?; (15) Was an attempt made to blind those measuring the main intervention outcomes?; (16) If any of the results of studies were based on "data dredging," was this made clear?; (18) Were the statistical tests used to assess the main appropriate outcomes?; (20) Were the main outcome measures used accurate (valid and reliable)?; (22) Were study subjects in different intervention groups (trials and cohort studies) or were cases and controls (case–control studies) recruited over the same period? (23) Were study subjects randomized to intervention groups?

2.10. Data synthesis

Studies were quantitatively synthesized and characterized by criteria of authors, year of publication, country, sample (number of participants, gender, and age) context (competitive level), game format, rules and procedure of the game, measure of creativity used, and primary outcomes. An additional analysis proposal was established by the authors for the identification of the area (m2) per player, bringing even more detailed data on the formatting of game spaces and offering more data for the planning of training processes based on reduced games in soccer aimed at the emergence of creative actions.

3. Results

3.1. Study selection

From main electronic databases searches, a total of 490 references were identified. After duplicated studies had been removed, 444 records remained. In the first screening step, 444 were assessed, and 9 were considered eligible for full-text reading. In the second step, 4 were excluded, two for not having cross-sectional design and two for not presenting creativity assessment measures in results. Therefore, only 5 papers met the inclusion criteria and were considered for qualitative synthesis. Within population, intervention, comparison, outcome and type of study specifications, no additional studies were found. The complete process of identification and selection of studies is provided in Figure 1.

3.2. Study characteristics

All included papers were classified as analytical cross-sectional studies according to the JBI reviewers manual, with the inclusion of a total of 134 participants. Studies were conducted in Spain (Torrents et al., 2016; Canton et al., 2019, 2020), Netherlands (Caso and van der Kamp, 2020) and Portugal (Santos et al., 2020) and were published between the years 2016 and 2020. In addition, only one study does not specify the gender of participants (Santos et al., 2020), while the other two are composed of male athletes (Torrents et al., 2016; Canton et al., 2019, 2020; Caso and van der Kamp, 2020). As for the context, two studies were composed of young soccer players (Canton et al., 2020; Santos et al., 2020); one was carried out with professional athletes (Caso and van der Kamp, 2020); another used two groups: amateur players enrolled in a sports sciences degree and professional athletes

TABLE 1 Characteristics of studies.

Authors (year)	Country	Sample	Context	Game format	Rules	Procedure	Measure of creativity	Primary outcomes
Torrents et al. (2016)	ESP	22 professionals ♂ Mean age of 25.6 years (SD = 4.9); 22 amateurs ♂ Mean age of 23.1 years (SD = 0.7).	Professional males from a single soccer and amateur male players enrolled in a sports sciences degree.	4 v 3 4 v 4 4 v 7 (40 × 30 m)	All SSG: official rules. In order to avoid the effect of the scoring, the scoreboard turned to 0 when any team achieved two goals.	2 × 3 min for each game format.	Notational analysis. Observation instrument adapted from Owen et al. (2014) and Costa et al. (2011).	Players seem to show more exploratory behavior when playing with numerical disadvantage.
Canton et al. (2019)	ESP	15 ♂ Under the age of 23 years. Mean age of 19.9 years (SD = 1.6); 15 ♂ Under the age of 15 years. Mean age of 13.8 years (SD = 0.4).	Each age group played in the same team and category. Under 23 group: Spanish 3rd division; Under 15 group: División de Honor, top level of the Spanish football league system of that age.	Balanced SSG: 4 v 4 (40 × 45 m); Imbalanced SSG: 4 v 4 5 v 4 4 v 5 6 v 4 4 v 6 (40 × 45 m)	Balanced SSG: fixed number of opponents. Imbalanced SSG: numerical change as follows: minute one: 4 vs. 4; minute two: 5 vs. 4; minute three: 4 vs. 5; minute four: 6 vs. 4; and minute five: 4 vs. 6. All SSG: official rules, except off-side and throw-ins. Goal kick reposition after a goal and throw-in.	2 × 5 min for each game format.	Positional data analysis.	The manipulation of the number of teammates and opponents at 1 min intervals promoted, in the Under 15, a slight increase in the exploratory behavior in both short- and long-term exploration breadth. In the Under 23, the same constraint promoted an unclear increase in the short-term exploration, and a very large increase in the long-term.
Canton et al. (2020)	ESP	24 ♂ Under the age of 12 years. Mean age of 11.3 years (SD = 0.8).	High-level soccer school and all of them had more than 1 year of experience in this school.	5 v 5 (31 × 37 m)	Three different situations of 5 v 5 SSG (front goals; right diagonal goals; and left diagonal goals).	6 × 5min for each goal positioning.	Positional data analysis.	Changing the positioning of goals in SSG in soccer modifies the originality of tactical behavior but does not seem to increase fluency and flexibility.
Caso and van der Kamp (2020)	NLD	24 ♂ 17 to 32 years. Mean age of 21.3 years (SD = 3.46).	Professional players affiliated with the same elite European soccer club and playing for their national team.	5 v 5 and 6 v 6 (36 × 18 m); 7 v 7 (54 × 18 m); 11 v 11 (105 × 64 m).	All SSG: official rules, except throw-ins. Goal kick repositions in these cases. 11 v 11 official match rules.	1 × 10 min for each game format.	Notational analysis. A score sheet was developed listing the definitions of creative soccer actions.	Players produced more creative actions in the three SSG-formats than in the 11-aside match. The number of original and creative actions seem to reduce increasing the pitch size, with none appearing during the 11 v 11.

(Continued)

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TABLE 1 (Continued)

Authors (year)	Country	Sample	Context	Game format	Rules	Procedure	Measure of creativity	Primary outcomes
Santos et al. (2020)	PRT	12 13 and 14 years. Mean age of 13.7 years (SD = 0.5).	Youth players with 6.1 ± 0.9 years of experience in soccer practice. All players were members of the same team.	4 v 4 (50 × 35 m); 6 v 6 (64 × 43 m).	Different balls were used in each game format and period of game (soccer, handball, rugby and mixed).	4 × 6 min for each game format, being the first bout using soccer ball, the second with handball, the third with rugby ball, and the last bout changing the ball type for each 2 min.	Creativity Behavior Assessment in Team Sports (CBATS).	4 v 4: fluency decreased with rugby ball compared to the soccer ball. 6 v 6: fluency and versatility decreased with the handball and rugby ball compared to the soccer ball; and fluency decreased with mixed balls compared to the soccer ball.

(Torrents et al., 2016); finally, one study used two groups of age categories: U-23 and U-15 (Canton et al., 2019). The practice time in the modality was explained in two of the three articles (Canton et al., 2020; Santos et al., 2020), being different between them.

With regard to procedures used to carry out games, the total time for each format and game specifications within studies varies between 6 and 30 min. One study analyzed the first 10 min continuously (Caso and van der Kamp, 2020), while the others divided them into different time periods (Torrents et al., 2016; Canton et al., 2019, 2020; Santos et al., 2020).

The instruments used to measure creativity ranged from analysis of positional data obtained through GPS equipment (Canton et al., 2019, 2020), notational analysis from a pre-established matrix for creative actions (Caso and van der Kamp, 2020), from a pre-prepared spreadsheet entitled Creativity Behavior Assessment in Team Sports (CBATS) (Santos et al., 2020) and from adapted observational instrument (Torrents et al., 2016). More information about study characteristics is provided in Table 1.

3.3. Risk of bias of studies

According to the JBI checklist for cross-sectional studies, all studies included at least 5 of the 8 items proposed in the instrument. Regarding item 1, three studies were not clear in describing the inclusion criteria (Canton et al., 2019, 2020; Santos et al., 2020). As for the standardization of the combination of groups, four studies made clear the use of a subjective division criterion based on the coach's decision (Torrents et al., 2016; Canton et al., 2019, 2020; Santos et al., 2020), while one does not determine the final criterion for this division choice of team composition (Caso and van der Kamp, 2020). The criteria referring to confounding factors were considered not applicable to the five studies (items 4 and 5). The full assessment of the risk of bias in individual studies is provided in Table 2.

3.4. Results of individual studies

Torrents et al. (2016) sought to verify how restrictions arising from changes in the number of opponents and teammates affect the exploratory behavior of 22 professional players and 22 amateurs, in 4 v 3, 4 v 5 and 4 v 7 reduced games, on a field with dimensions of 40 × 30 m. The two amateur teams that played with fixed number of 4 players, called AMAa and AMAb, showed effects of the number of opponents. By analyzing the exploration values between different small game formats, AMAa showed small effect of the number of opponents when comparing games with 5 and 7 opponents. AMAb showed strong effects of the number of opponents when comparing 3 and 5 opponents, and also between 3 and 7 opponents. The two professional teams with fixed number of players, named PROa and PROb, showed moderate effects when comparing games with 3 and 5 opponents, and between 3 and 7 opponents. In the case of variable teams, playing with seven teammates clearly produced lower exploratory breadth compared with the other conditions. All teams showed strong effects of the number of teammates when comparing 5 and 7 teammates, and 3 and 7 teammates.

Canton et al. (2019) verified exploration rate and breadth values for temporary numerical balanced and unbalanced numerical

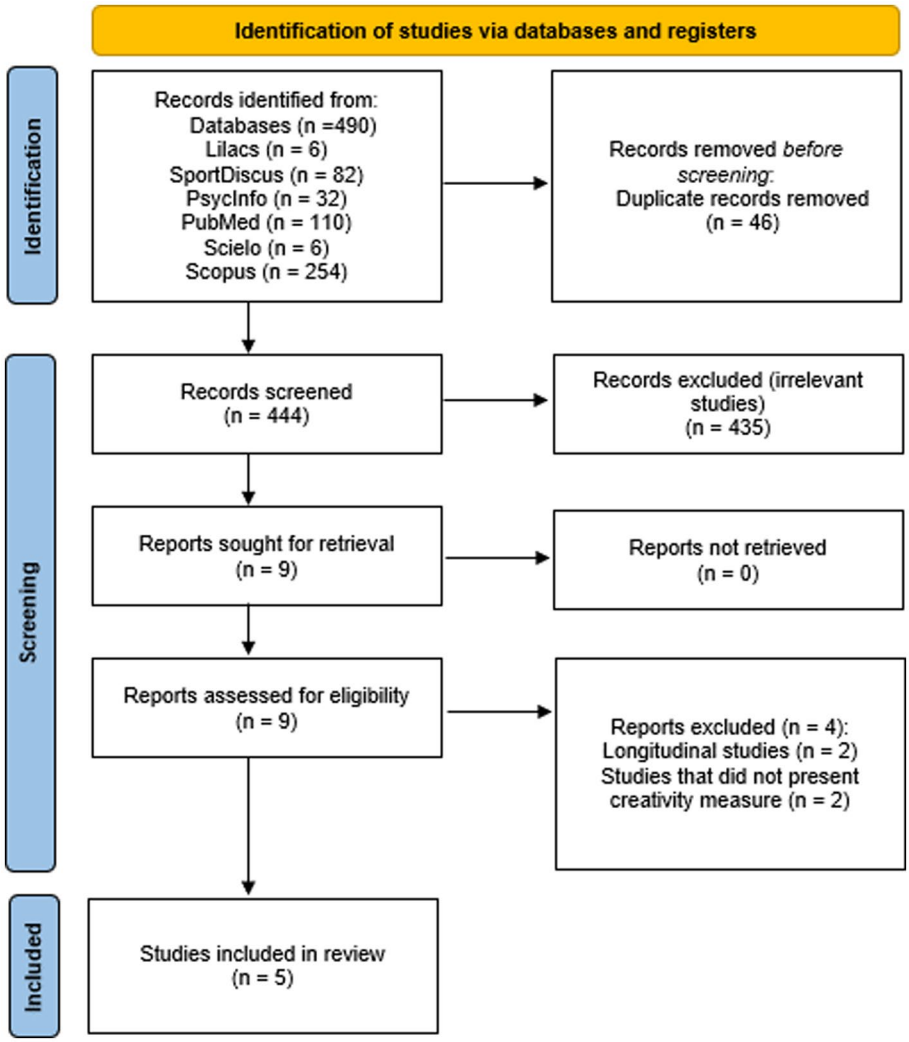

FIGURE 1
PRISMA flow diagram highlighting the selection process for the studies included in the current systematic review (Adapted from Page et al., 2021).

TABLE 2 Assessment of the risk of bias in individual studies.

Authors	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Quality assessment
Torrents et al. (2016)	✓	✓	✓	✓	N/A	N/A	✓	✓	6
Canton et al. (2019)	U	✓	✓	✓	N/A	N/A	✓	✓	5
Canton et al. (2020)	U	✓	✓	✓	N/A	N/A	✓	✓	5
Caso and van der Kamp (2020)	✓	✓	✓	U	N/A	N/A	✓	✓	5
Santos et al. (2020)	U	✓	✓	✓	N/A	N/A	✓	✓	5

Q1. Were the inclusion criteria in the sample clearly defined? Q2. Were the study subjects and the setting described in detail? Q3. Was the exposure measured in a valid and reliable way? Q4. Were standard criteria used for measurement of the condition objective? Q5. Were confounding factors identified? Q6. Were strategies to deal with confounding factors stated? Q7. Were the outcomes measured in a valid and reliable way? Q8. Was statistical analysis used appropriate? ✓ - Yes; –- - No; U – Unclear; N/A – Not/Applicable. (Moola et al., 2020).

conditions for each age group and SSG condition for two distinct age groups. For the age group under 23 years, increase in exploratory breadth was observed and the exploration rate showed unclear effects. For the under 15 age group, the mean exploratory breadth value clearly decreased using temporary numerical imbalances from an equilibrium situation. The exploitation rate reported that its average value would likely be reduced from a numerical equilibrium situation to a temporary numerical imbalance situation, with small effect size.

Canton et al. (2020) assessed 24 athletes (aged under 12 years) in three different situations of small-sided games with a 5 v 5 configuration, in which goals were positioned in front, diagonally to the right, and diagonally to the left relative to the direction of the attack of teams, and the field dimensions were set at 37 × 31 m. Based on the analysis of principal components extracted from the metrics observed through positional data analysis obtained by GPS tracking, it was observed that teams perform their behaviors differently

depending on the type of structural constraints of the game. When positioning the goals diagonally, there is variation in the measures of some components, such as team length and width, centroid angle, distance from the centroid to the own goal, and sectors and corridors traveled. In this sense, tasks can be proposed to achieve training objectives related to spatial organization or tactical behaviors based on the practice of unusual scenarios, these atypicalities being related to an environment that favors originality.

Caso and van der Kamp (2020) examined variability and creativity in small-sided games of 5 v 5 (36 × 18 m), 6 v 6 (36 × 18 m), 7 v 7 (56 × 18 m), as well as formal 11 v 11 (105 × 64 m) games in a group of 24 professional players aged 17–32 years affiliated with the same elite European soccer team. Analysis of variance in the number of actions revealed significant effects of game format, and descriptive statistics show that the smaller the game format, the greater the total number of actions performed by players. Furthermore, *post-hoc* analyses indicated significant differences in favor of all small-sided game formats compared to the 11 v 11 game, and also in favor of 5 v 5 compared to 7 v 7. Regarding variability, the effect of game format was observed, with *post-hoc* analyses detecting the production of actions from more categories in all small-sided game formats compared to the formal game. Originality was recognized from categories of actions that were exclusively produced by one or two players (approximately 5% of participants), resulting in 14 actions from 6 distinct categories of actions. Of these actions, 10 were considered creative and appropriate. Descriptive statistics recognized higher total number of original and creative actions in smaller game configurations; however, inferential statistics could not be performed due to the low number of actions.

Santos et al. (2020) identified creative components incorporated into technical skills in 4 v 4 (50 × 35 m) and 6 v 6 (64 × 43 m) small-sided games with manipulation of ball type in a group of 12 young players from the same team. When compared, fluency using a rugby ball within both formats of small-sided games was considerably reduced compared to the use of a soccer ball. Additionally, in the 6 v 6 formats, fluency also decreased significantly when comparing the use of a soccer ball with that of a rugby ball, and there may have been a decrease in fluency in the comparison between a soccer ball and a handball. Finally, the versatility component also decreased when comparing the soccer ball to the handball and rugby balls.

3.5. Confidence in cumulative evidence

According to evaluation based on the adaptation of the critical appraisal instrument Quality Index (Downs and Black, 1998), studies by Torrents et al. (2016) and Canton et al. (2019) met 9 of the 14 items used (64.29%), while Canton et al. (2020) and Santos et al. (2020) met 8 (57.14%) of the items. Finally, the work by Caso and van der Kamp (2020) met 10 (71.43%) of the items. Further details regarding the evidence appraisal are available in Table 3.

3.6. Additional analysis

In order to make the graphic representation of the additional analysis regarding the field area (m2) per player more accessible, the values of evaluated creativity components were converted to a scale

TABLE 3 Critical appraisal of studies includes in systematic reviews.

Authors (year)		Criteria																
		1st	2nd	3rd	6th	7th	10th	11th	12th	15th	16th	18th	20th	22nd	23rd	*n*	%
Torrents et al. (2016)		1	1	1	1	1	0	0	0	0	1	1	1	1	0	9	64.29
Canton et al. (2019)		1	1	1	1	1	0	0	0	0	1	1	1	1	0	9	64.29
Canton et al. (2020)		1	1	0	1	1	1	0	0	0	1	1	1	0	0	8	57.14
Caso and van der Kamp (2020)		1	1	1	1	0	1	0	1	0	1	1	1	1	0	10	71.43
Santos et al. (2020)		1	1	0	1	1	0	0	0	0	1	1	1	1	0	8	57.14
Total	*n*	5	5	3	5	4	2	0	1	0	5	5	5	4	0		
	%	100.00	100.00	60.00	100.00	80.00	40.00	00.00	20.00	00.00	100.00	100.00	100.00	80.00	00.00		

1st: Is the hypothesis/aim/objective of the study clearly described? 2nd: Are the main outcomes to be measured clearly described in the Introduction or Methods section? 3rd: Are the characteristics of participants included in the study clearly described? 6th: Are the main findings of studies clearly described? 7th: Does the study provide estimates of the random data variability for the main outcomes? 10th: Have current probability values been reported (e.g., 0.035 rather than <0.05) for the main outcomes except where the probability value was less than 0.001? 11th: Were subjects asked to participate in the study representative of the entire population from which they were recruited? 12th: Were subjects who were prepared to participate representative of the entire population from which were they recruited? 15th: Was an attempt made to blind those measuring the main intervention outcomes? 16th: If any of the results of the study were based on "data dredging," was this made clear? 18th: Were the statistical tests used to assess the main appropriate outcomes? 20th: Were the main outcome measures used accurate (valid and reliable)? 22nd: Were study subjects in different intervention groups (trials and cohort studies) or were cases and controls (case–control studies) recruited over the same period? 23rd: Were study subjects randomized to intervention groups? 0 – No/Unable to determine; 1 – Yes (Downs and Black, 1998).

from 0.00 to 10.00, assigning "10.00" to the highest value in each study and calculating the remaining values proportionally.

Torrents et al. (2016) used unbalanced small-sided games with four fixed teams of 4 players (AMAa; AMAb; PROa; PROb) against teams with 3, 5, and 7 opponents (AMAc; AMAd; PROc; PROd). The 4 v 3, 4 v 5, and 4 v 7 game formats corresponded to relative areas of 171.43 m2/player, 133.33 m2/player, and 109.09 m2/player, respectively. The aforementioned authors relate the increase in exploratory behavior to the numerical relationship between teams, with the disadvantaged teams exhibiting higher exploratory behavior. Furthermore, the additional analysis of the present study demonstrates that in addition to the numerical disadvantage, the relative playing area can also be an indicator. Performing the proposed scalar conversion, the game format with 171.43 m2/player presented values of 8.42 for AMAa, 7.27 for AMAb, 8.00 for PROa and PROb. As for the game played in a space with relative area of 133.33 m2/player, AMAa (8.42), AMAb (9.41), PROa (9.41), PROb (8.42) start to show higher exploratory behavior values. Finally, by further reducing the relative playing area (109.09 m2/player), the trend of increasing the breadth of exploration remains for teams, with AMAa showing value of 8.42, AMAb 10.00, PROa 9.41, and PROb 8.88 (Figure 2).

Canton et al. (2019), when analyzing balanced games (4 v 4) and unbalanced games where the number of players involved in the match changed every minute (min 1: 4 v 4; min 2: 5 v 4; min 3: 4 v 5; min 4: 6 v 4; and min 5: 4 v 6), also found increase in exploratory behavior for unbalanced matches. In this regard, it is worth noting that the alternation of players in small-sided games causes changes in the relative area per player over time, as it is reduced with each change in the game format (Figure 3).

Canton et al. (2020) used the same configuration regarding the field dimensions and number of players, manipulating only the positioning of goals. For a 5 v 5 game in which field measurements were 31 × 37 m, the relative area was 114.70 m2 per player. Regarding the proposed scale conversion, the game with front goals presented higher exploration rate values (10.00), followed by goals to the right (9.15) and goals to the left (8.94). For the exploration breadth, the results observed for goals to the right were higher (10.00) when compared to the front position (9.46) and to the left position (9.40) of goals (Figure 4).

Caso and van der Kamp (2020) used several game configurations, with different field dimensions and number of players. The 5 v 5 game played on a 36 × 18 m field represented a relative area of 64.80 m2/player and had the highest value of original and creative actions (10.00). When playing 6 v 6 on the same field (36 × 18 m), the relative area decreased to 54.00 m2/player and the proportional value assigned was the second highest (6.67). For larger game formats, the 7 v 7 on a 54 × 18 m field (relative area of 69.43 m2/player) showed a decrease in creative actions (3.33), while the 10 v 10 on a 105 × 64 m field (relative area of 336.00 m2/player) had no creative actions at all (0.00) (Figure 5).

The original study by Santos et al. (2020) did not propose a comparison between game formats, thus no inferential statistics were performed to analyze whether there are differences in creativity measures between 4 v 4 and 6 v 6 matches. However, considering the descriptive analysis, it is possible to observe that the median fluency and versatility values for each type of ball used either remained the same or decreased as the number of players and relative area per player increases, except for the game that used only the soccer ball. Assigning the proposed conversion in this additional analysis to the aforementioned study, the 4 v 4 game with dimensions of 50 × 35 m (relative area per player of 218.00 m2/player) obtained better values for the fluency component than the 6 v 6 game with dimensions of 64 × 43 m (relative area per player of 229.33 m2/player) using handball (10.00 vs. 7.50), rugby ball (6.67 vs. 5.00), and mixed ball

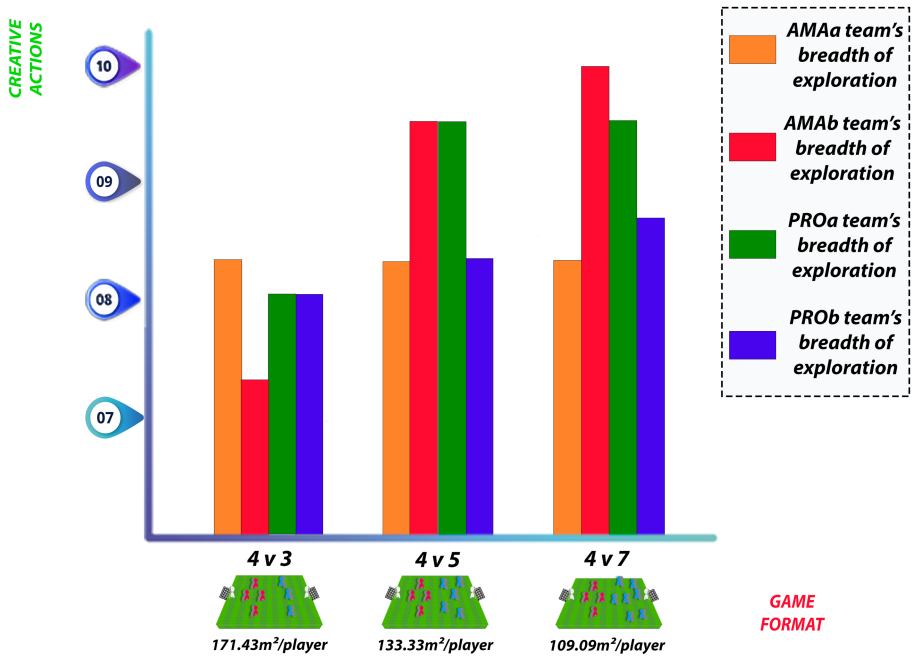

FIGURE 2
Breadth of exploration of teams for different relative playing areas.

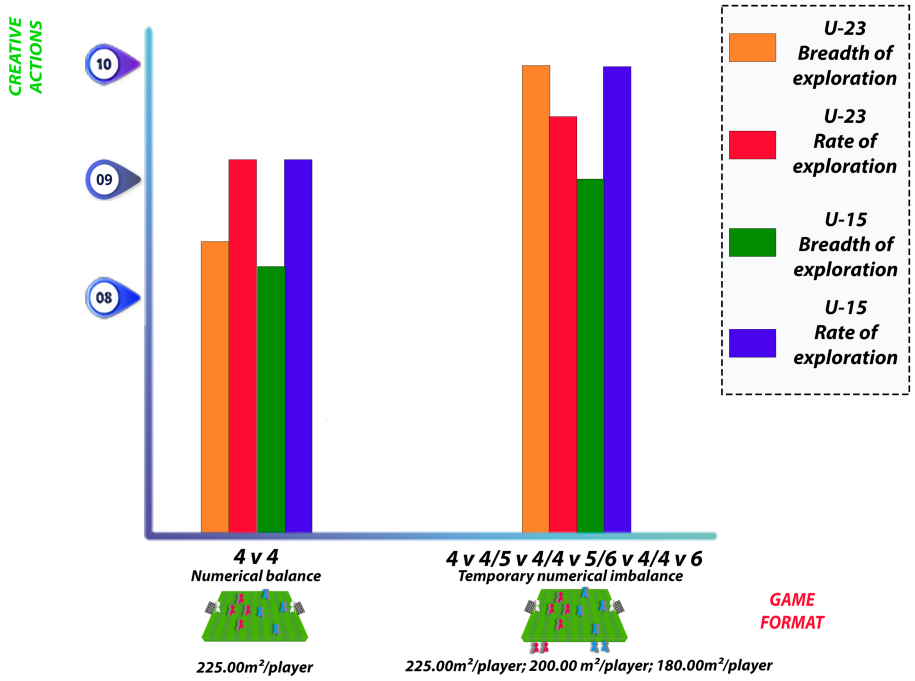

FIGURE 3
Rate and breadth of exploration for balanced and unbalanced game formats.

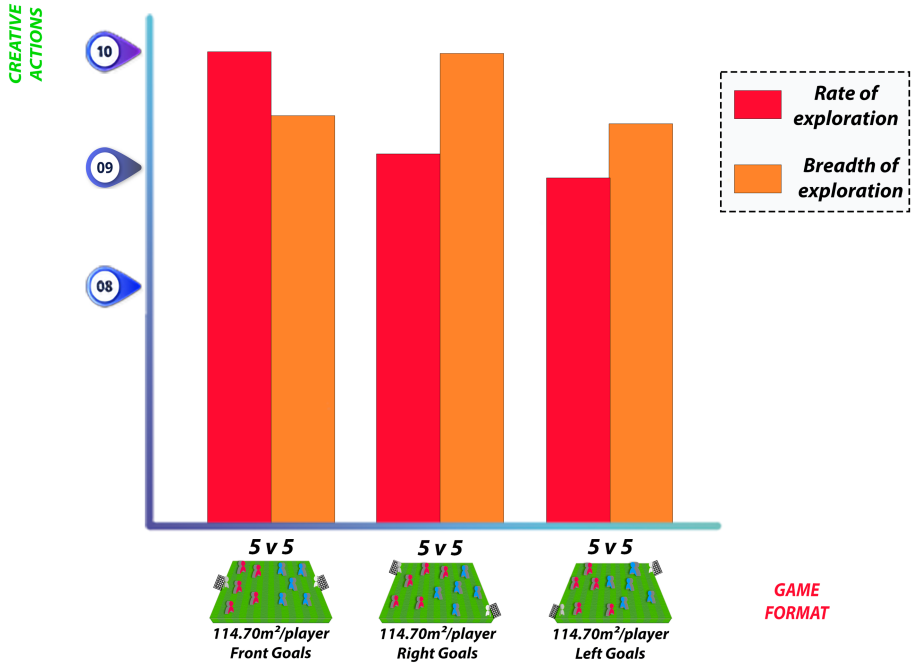

FIGURE 4
Exploration rate and exploration breadth for relative area of 114,70 m²/player.

(8.33 vs. 5.00), with the larger format only having an advantage with the soccer ball (8.33 vs. 9.17). On the other hand, versatility only presented different values between the 4 v 4 and 6 v 6 when using handball (1.67 vs. 0.00), also in favor of the smaller game format (Figure 6).

4. Discussion

This review aimed to investigate the impact of the number of players on the emergence of creative movements in small-sided soccer games, emphasizing studies carried out in a deliberate practice

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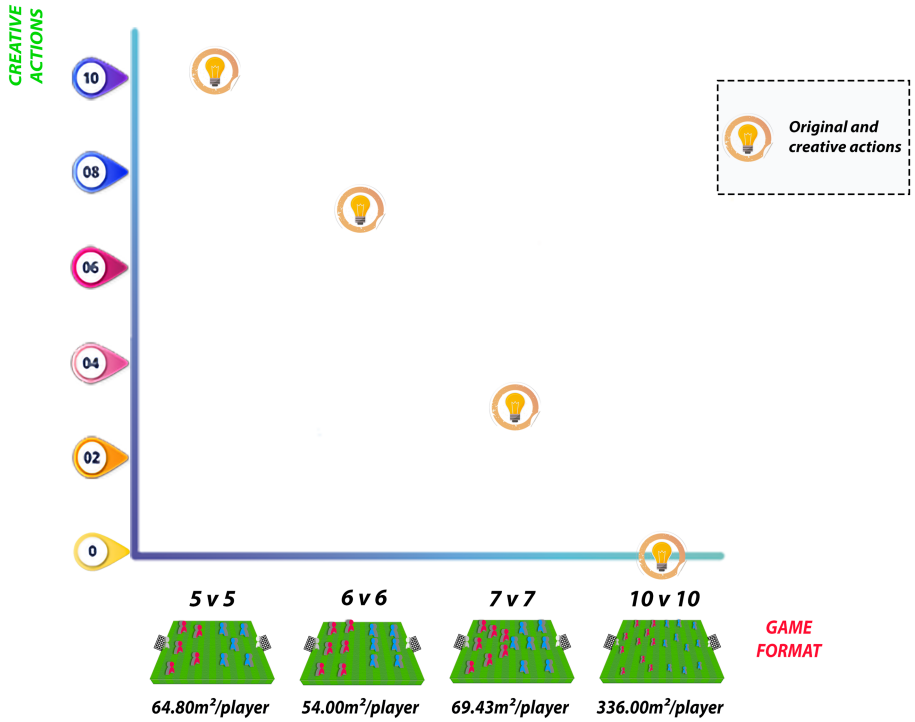

FIGURE 5
Original and creative actions for different relative areas per player.

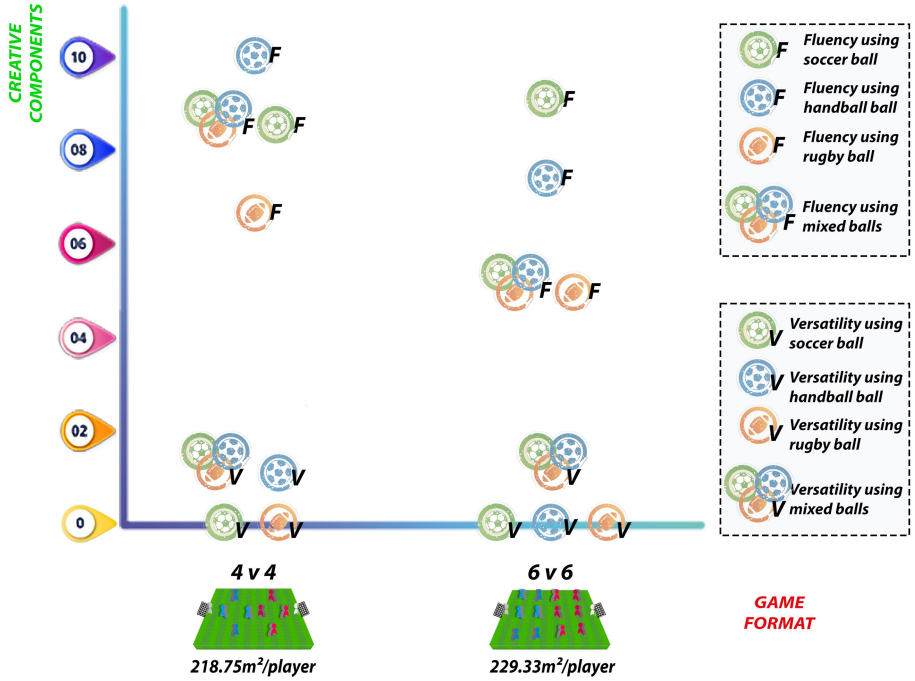

FIGURE 6
Fluency and versatility in different relative areas and with ball type manipulation.

context. We hypothesized that smaller game formats, with fewer participants, reduce the possibilities of interactions between teammates for problem-solving, increasing exploratory behaviors in the playing space that enable the emergence of new, original, useful and problem-oriented actions. Following this reasoning, other manipulations that favor an increase in exploratory behavior could

also contribute to the emergence of creativity. The present review found five articles that met the criteria, which is a low number with high heterogeneity in protocols, having very distinct creativity procedures and measures among them. This fact prevented the conduction of a meta-analysis and indicates the need for more research on the topic. The results found in the present study confirmed the expectation that the number of players impacts creativity measures, supporting the idea that smaller games favor the emergence of creative actions compared to formal matches. Additionally, it was also identified that structural changes in small-sided games can generate unusual environments in which different tactical responses may favor originality in actions. However, concerning the manipulation of different ball types, values related to creativity variables did not improve when using different balls.

4.1. Creativity measurement

The fact that the present review found studies that used different methods to measure creativity is also due to the epistemological possibilities of understanding the phenomenon, which can be translated through the choice of creativity instruments and measures to be evaluated. In the cognitive perspective, studies on creativity in sports follow the precepts of psychology, appropriating and presenting the fluency, flexibility, and originality constructs. Studies using this perspective for small-sided games can have observational nature, in which evaluators or experts can quantify the different actions for a specific situation (fluency), or also how many different types of solutions were generated for these situations (flexibility), or how appropriate and rare these solutions were (originality). In this sense, both game observation and game test situations (GTS) stand out as notation procedures. Memmert and Roth (2003) proposed the scale to evaluate actions within GTS, in which aspects related to flexibility and originality are verified based on a classification from 1 to 10, for which there is a description of requirements of actions for each of the scalar levels. Another possibility of instrument and variables to measure creative actions is the Creativity Behavior Assessment in Team Sports - CBATS, a tool developed to measure the individual creativity in ball possession during the game performance, identifying whether an action is standardized or non-standardized, and allowing the analysis of attempts, fluency, and versatility variables, expanding creativity measures (Santos et al., 2017, 2018). There is also the perception that the production of actions from more than one category (a large repertoire of actions) can be considered as variability, consisting of a criterion for evaluating creativity (Caso and van der Kamp, 2020).

Considering the studies included in the present review, the notational analysis presented by Santos et al. (2020) measured the frequency of passes, dribbles and shots, which were divided into success and failure. In this way, unsuccessful actions could be framed as failures or attempts, while successful actions consists the distinction between fluency and versatility. For this last classification, the observational matrix included the existence of criteria that determine whether an action is standardized or non-standardized, respectively.

Furthermore, Caso and Van der Kamp (2020) considered an observational matrix with a range of actions with and without the ball, divided among different arrangement. Variability could be verified based on the number of different categories of actions explored. Regarding the measure of originality, actions performed by approximately 5% of players or less received this rating. When the behavior was correct and appropriate, it was considered creative solution.

Studies based on the ecological premise argue that the game consists of dynamic social structures and that coordination emerges from interaction between system components. These investigations tend to be developed with other measures and, consequently, other instruments for assessing creativity. Variability and unpredictability are constructs that gain prominence and are assessed through entropy measures, whose calculation allows understanding the disorder or uncertainty measure in the system. Low entropy values reflect decrease in unpredictability, while high values indicate increase in the minimum information needed to describe the system and, consequently, greater variability (Silva et al., 2016). Another variable related to creativity is exploratory behavior, which considers the breadth of the variety of exploratory responses generated in a given system, as well as its exploration rate, which can be obtained through information extracted from global positional tracking systems, such as team amplitude and depth, centroid angle, centroid velocity, centroid distance from the goal, among others (Canton et al., 2020), or also focused on quantifying the technical-tactical actions of attackers with and without the ball and of defenders, performed within small-sided games to obtain exploration values from an observational matrix (Torrents et al., 2016).

Regarding measures of collective exploratory behavior during games, Torrents et al. (2016), Canton et al. (2019), and Canton et al. (2020) analyzed the average dynamic overlap, whose measurement allows capturing the average similarity between configurations or game patterns with each increase in the determined time distance. In this way, it becomes possible to detect measurements of the rate and breadth of exploration over different time scales.

4.2. Number of players in small-sided soccer games and the impact on tactical behavior

Variations of small-sided games in soccer can induce different tactical, technical, physical, and physiological responses in players (Praça et al., 2022). Regarding the tactical dimension, literature review and meta-analysis studies on convergent behavior in small-sided soccer games have already been developed (Sarmento et al., 2018; Clemente et al., 2022). In this line, studies have concluded that the manipulation of this constraint leads to the emergence of new patterns of tactical behavior and interactions among players (Ometto et al., 2018). This is observed in a primary study comparing 3 v 3 and 6 v 6 small-sided games, where the smaller configuration generates an environment in which players perform more aggressive actions, seeking more movements toward the opposing goal and one-on-one duels (Silva et al., 2014), which can be explained by the decrease in the number of collective possibilities to solve problems and the need to enhance individual skills as a resource for solving different game scenarios.

Regarding creative actions (divergent tactical behavior), the results in literature so far indicate the possibility of smaller formats of small-sided games being more favorable. Ric et al. (2016) highlighted how manipulating the numerical ratio between teams in small-sided

games produce changes decision-making and tactical aspects, as the increase in the number of opponents within the game results in decrease in exploratory breadth, unpredictability, and flexibility. The analysis conducted by Torrents et al. (2016) focused on observable motor behavior, finding that players seem to show more exploratory behavior when playing with numerical disadvantage. Disadvantage forces players to vary the game, while numerical advantage seems to produce less exploration and variety. However, it is evident that playing in an unbalanced way can change the exploratory behavior of players (Canton et al., 2019). The study by Caso and van der Kamp (2020) advances in this direction and, although studies on creativity are still scarce, it suggests that the dynamics in smaller small-sided games lead players to produce more tactical actions of large number of different categories, resulting in more original and creative actions. What is also subject to discussion is that, in the aforementioned study, the 5 v 5 format stood out over larger formats that also used larger field dimensions (7 v 7 and 11 v 11); however, there was no significant difference in the number and variability of actions for the 6 v 6 format in which the field size was the same, leading us to believe that this is also a variable to be investigated.

4.3. Pitch size and manipulation of targets

The dimensions of the field in small-sided games represent an important object of study for tactical actions, as they provide the delimitations of the playing space and influence the space and time for solving a given problem. Ometto et al. (2018) analyzed how manipulating the field size influences tactical behaviors related to positional relationships and concluded that reducing the playing space favors the closeness between players on the same team, increases the amount of dribbling, and makes decision-making more difficult. However, a study by Clemente et al. (2022), while corroborating the idea of player proximity in smaller fields, synthesizes results regarding technical aspects and presents ambiguous data, with some studies showing better dribbling values for smaller fields while others attribute more expressive values to larger small-sided games, attributing the differences to the procedures of primary studies using different protocols.

What seems to be a consensus is that, in the context of soccer training, finding the most appropriate formatting can promote in players an adaptation that favors affordances (opportunities to act) in various situations within the task (Rico-González et al., 2022). In this sense, and more focused on providing an environment that enhances creative actions, the present study sought a calculation of the relative area per player (calculated as the field area divided by the number of players involved in the game), as variations in this relative space can change athletes' responses (Clemente et al., 2022). The previous study by Vilar et al. (2014) aimed to understand whether altering the dimensions of the field in 5 v 5 games has the potential to shape opportunities for ball possession, passing to teammates, and shooting at the goal. Small (28 × 14 m; 39.20 m2/player), medium (40 × 20 m; 80.00 m2/player), and large (52 × 26 m; 135.20 m2/player) field configurations were used in matches, finding that a decrease in playing space provides better opportunities for ball possession, without influencing passing and shooting to teammates. Supporting the information that larger game configurations result in environment with lower number of individual player actions, other studies have also found differences in passing and shooting (Casamichana and Castellano, 2010; Owen et al., 2014). Considering that creative actions in studies largely evaluate actions related to the offensive phase, the literature seems to indicate the importance of smaller structures.

Corroborating the information previously presented, the additional analysis of the relative area per player in studies included in this review demonstrated that smaller structures, such as 5 v 5 (64.80 m2/player) and 6 v 6 (54.00 m2/player), provided an environment with higher absolute values of original and creative actions when compared to 7 v 7 (69.43 m2/player) and 10 v 10 (336.00 m2/player) games (Caso and van der Kamp, 2020). Based on results of the aforementioned study, reducing the number of players seems to favor creativity. Regarding the relative area per player, the comparison between 336.00 m2/player, 69.43 m2/player, and 54.00 m2/player seemed to indicate a trend toward increasing creativity as the field measures per player decreased. However, the smallest relative area (54.00 m2/player) for the 6 v 6 match did not present more creative and original actions than the 5 v 5 match with larger relative area (64.80 m2/player), making this assumption inconclusive. Based on these findings, it is important to consider the reduction of the relative area per player together with the numerical composition of reduced matches. Additionally, the study by Santos et al. (2020) also shows the possibility of obtaining better creativity measures by manipulating ball type, relying more on smaller space (4 v 4 with 218.75 m2/player) than on larger one (6 v 6 with 229.33 m2/player), also considering in this study that the increase in the number of players may be a significant factor.

Another relevant point is the manipulation of goals. As already mentioned, the constraints related to the number of players and field dimensions in small-sided games have potential to alter variables related to the positioning of these players, such as centroid, dispersion, and distance between players. In a 5 v 5 context, Canton et al. (2020) identified that by positioning the goals at different ends of the field, the measures obtained through tracking the movements within the playing field become distinct, relating the findings to the possibility of using it as a tool for actions different from usual, increasing the potential for originality present in small-sided game environments.

4.4. Variability and differential learning environments in deliberate practice

Based on the premise that variability is related to the emergence of creative movements since innovative and appropriate actions can arise from variation in the manipulation of the environment and task, inviting individuals to explore different ways of adapting to constraints, the study by Caso and van der Kamp (2020) clarifies that small-sided games tend to favor players exploring more actions.

Similarly, Santos et al. (2020) added another variability strategy to two formats of small-sided games. Based on other studies that have shown the importance of training with balls of different sizes and weights to improve motor skills, their study did not find improvement in variables related to creativity when playing small-sided games with balls other than those specific to the sport of soccer. Although the authors themselves recognize the importance of previous studies that, by analyzing longitudinally and through a training program with less

habitual dynamics, found improvements in tactical actions, decrease in creativity indicators when using different ball types should not discourage this approach. The approximation of characteristics of a non-linear differential learning pedagogy and, consequently, the shift from a traditional view should consider the importance of error in skill acquisition, not focusing on correction and repetition as sources of learning, and providing environment with infinite technical variations of movement in order to make the individual able to deal with changes in games (Schollhorn et al., 2012).

A long-term deliberate practice based on games with high variability is beneficial. The study by Coutinho et al. (2018) involved young players from under-15 and under-17 categories and found improvements in physical, technical, tactical, and creative aspects for groups that participated in a physical literacy training program (control) as well as for differential learning (experimental) groups, with the second group using different balls throughout the program among other manipulations to increase variability. Furthermore, the study found better creativity scores for the experimental group in the under-15 category, corroborating stages described in the creativity development model proposed by Santos et al. (2016), whose age group (13–15 years) corresponds to the creator stage and precedes the emphasis on actions focused on specialization, and emphasizes the importance of diversification in the process. The study by Santos et al. (2018) with under-13 and under-15 categories confirms a tendency toward improvement in fluency, originality, flexibility measures, and elaboration for groups exposed to a training program that provides environment with greater need for adaptation and variations by practitioners.

4.5. Practical applications and study limitations

The current paper systematically brings together preliminary information and evidence that allow better knowledge of the state of the art, based on research and tests that evaluate the creativity in small soccer games, to provide interested teachers, coaches, and researchers in the thematic subsides for the choice of more accurate game configurations within the training processes.

This study has some limitations. First, in relation to the lower number of studies found that do not demonstrate an existing reproducibility of evidence synthesized so that they can be indicated as a practical solution to the central problem of this research. The second point is that the creativity measures found in different studies were also varied, which does not allow grouping and comparing them. Finally, regarding the characteristics of studies, although two were developed with young players, one had professional players as participants, making studies heterogeneous in this sense.

For future research, it is recommended to consider the importance of the game format in creativity, also highlighting the relationship between the dimensions of the field and the number of players occupying the space. Additionally, other task constraints can be explored and combined, such as manipulating the type of ball, modifying the rules of the game, varying the number and positioning of targets, limiting the number of touches on the ball, the presence of jokers, among other structural and functional modifications to the game.

5. Conclusion

The number of players is an important variable to consider when setting up small soccer games aimed at providing favorable environments for the emergence of creative movements. The individual, the main agent of tactical decisions within the game, must be offered situations that make it easier to increase the number of actions performed, the variability of actions and, consequently, the number of original and creative movements. In this sense, small-sided games with fewer components seems to be more favorable than large spaces and more players, with decreases in creativity measures being found as the game configuration increases. The relative area per player still needs to be further investigated, but it seems to be an important component to consider when thinking about the tactical scenarios of small-sided games and their influence on the emergence of creative actions. In addition, it is possible to perceive that other manipulations can be inserted in the context of reduced games, with the intention of influencing tactical and technical behaviors, establishing regulations that in the long term can be important to diversify and increase the creative repertoire of players.

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

LU: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. MM: Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. GP: Data curation, Formal analysis, Investigation, Project administration, Writing – original draft, Writing – review & editing. GM: Data curation, Investigation, Writing – original draft, Writing – review & editing. JS: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – review & editing. PB: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing – original draft.

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Conflict of interest

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

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Children can rate perceived effort but do not follow intensity instructions during soccer training

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The perception of effort is elementary for the self-regulation of exercise intensity in sports. The competence for rating perceived effort (RPE) seems to be related to physical and cognitive development. Children accurately rate perceived effort during incremental exercise tests when loads progressively increase, but it remains unclear how children perform when they participate in sports games, which are characterized by complex tasks with varying intensity profiles. The present study investigates children's competencies for rating perceived effort and producing predetermined intensities during soccer training. Twenty-five children aged 11–13 years performed two similar training sessions. In the first session, the children trained without intensity instructions and continuously rated their effort. In the second session, the children were instructed to produce predefined intensities. Before the first training session, executive functions were assessed by cognitive performance tests and a self-report measure. RPE correlated significantly with heart rate measures ($R^2 = 0.27$, $p < 0.001$). As confirmed by factor analysis, individual differences in these correlations were related to the outcomes of the cognitive tests and the self-report measure. RPE in training session 2 differed from RPE in training session 1 ($d = 1.22$, $p < 0.001$), although the heart rate data did not differ significantly between training sessions ($d = -0.19$, $p = 0.780$). Thirteen-year-old children performed significantly better than eleven-year-old children ($d = 1.69$, $p = 0.027$). The results suggest that children are able to rate perceived effort during soccer training and that this ability is related to executive functions. Conversely, children may not be able to alter their intensities in response to instructions, although their ratings suggest that they have largely succeeded in doing so.

KEYWORDS

perceived effort, perceived exertion, RPE, executive functions, selfregulation, children, soccer

1. Introduction

The majority of sports activities are performed without a trainer or teacher supervising the performance. Accordingly, athletes regulate movement intensities autonomously. The principle component of goal-directed intensity regulation in sports is considered to be an adequate subjective perception of effort (1, 2). The competence for rating perceived effort (RPE) is typically evaluated by correlating RPE with objective measures such as heart rate (HR) or oxygen uptake. It is assumed that the RPE-competence improves with age. For example, Rice et al. (3) observed lower correlations between RPE and heart rate in six- to eight- than in eleven- to twelve-year-old children. Yelling et al. (4) described lower correlations in eleven- and twelve- compared to fourteen- and fifteen-year-olds. Conversely, other studies found large and excellent correlations between RPE and HR or performance measures already in nine- and twelve-year-olds (5, 6). Thus, several factors

appear to influence how well children can rate perceived effort. One factor is the applied rating scale. For example, Lamb et al. (5) reported higher correlations between RPE and HR in children when effort was rated with a child-specific rating scale compared to the Borg scale, which is the standard scale used for adults. Child-specific scales should include numerical and pictorial representations of effort to support understanding (7). Other factors discussed are the exercise type as well as the familiarity with the scale, the task and intensity ranges (7–9). Finally, RPE-competence depends on cognitive development which may explain differences between age groups as well as the advantages of child-specific rating scales (3, 9, 10).

Relationships between RPE competence and cognitive abilities have been reported for adults. Arnhold et al. (11) found that people with intellectual disabilities (ID) show lower correlations between HR and RPE during incremental exercise tests than people without ID. Schmitz et al. (12) reported similar findings in a field study on soccer training. As a sports game, soccer is characterized by complex tasks with open outcomes and temporally varying intensity profiles. The authors found that the HR measured at the time when effort was rated (current heart rate—cHR) explained one portion of the RPE variance thereby indicating that the current energetic effort contributes to RPE (13). Another portion of the RPE variance was explained by the cumulated training time, suggesting that also cumulative intensity effects contribute to RPE. Differences between people with ID and without ID were evident regarding the variance component explained by cHR. They were partially explained by performance differences in tests measuring the speed of cognitive information processing and flexibility, which are components of the executive control system (14). Schmitz and Sommer (15) amended these findings in another study on soccer training. RPE-variance explained by cHR was again related to the speed of information processing as well as to self-report measures of executive functions. RPE-variance explained by cumulated training effects, which were assessed with Edwards' summated heart rate zone method (sHRz) (16), was not related to performance in the cognitive tests. In summary, these studies suggest a relationship between executive control and the component of RPE explained by cHR but not the component explained by sHRz. Whether similar relationships exist in children is unclear. Since children's executive functions are not yet fully developed, this may explain why some studies found differences between the RPE-competences of different age groups [see also (3, 10)]. The present study investigates the hypothesis of a relationship between executive control and the variance component of RPE explained by cHR in children. The study applies the estimation paradigm from Schmitz and Sommer in children performing soccer training (15). It has been shown for adults, that cHR and sHRz explain independent variance components of RPE (15). Correlations between cHR and RPE are also evident in children [*e.g.* (3, 5, 6),]. sHRz correlates with session RPE which is a subjective measure for the training load of a sport activity. Medium correlations have been reported for eleven-year-old children ($r = 0.34$) playing soccer. Medium to high correlations have been shown for twelve- to seventeen-year-old children and adolescents (r ranging from 0.48 to 0.90) playing soccer or performing other sport-activities (17–22).

The first part of the present study focuses on the estimation of intensities whereas the second part investigates self-regulation of exercise intensities. Self-regulation of exercise intensities is typically investigated with a production paradigm, in which participants produce externally instructed intensities (23). Although this form of self-regulation builds on the perception of effort, it addresses further skills (24). For example, the perception of effort is based on afferent feedback as well as feedforward anticipation of imminent movement effects, whereas intensity regulation requires the prediction of future exertion states on a time scale from minutes or hours. This prediction is continuously compared with the intended state, on the basis of which motor output is adjusted (23, 25).

Studies have shown that children are capable of producing externally instructed intensities. Previously, the majority of studies applied incremental exercise tests (23) with loads that increase continuously. The predictability of future loads may simplify the rating of perceived effort and intensity regulation. Conversely, when children perform sports in a natural environment, their activities are characterized by changing intensity requirements. It is plausible to assume that the natural environment further increases the demands on self-regulation. However, few studies have investigated the production competence with randomly varying intensities. Children aged seven to eleven years were able to consistently produce three randomly varying intensity levels during cycle ergometry and stepping (26) thereby indicating that children can also meet this challenge. Lamb (5) stated that production in a controlled laboratory setting might be performed differently compared to production in an external valid setting like a physical education class. Accordingly, children aged six to eleven years seem to perform worse during a physical education class. In a study from Cowden and Plowman (27), 38% percent of children were not able to regulate exercise intensities within a defined HR range from 130 to 180 beats per minute. 60% showed inconsistent performance over time. These results suggest that these children may not have had the ability to estimate or produce intensities during a physical education class. As such, whether children have the ability to produce intensities in sporting situations with varying intensities remains unknown. The second part of the present study tested the hypothesis that children are able to produce prescribed intensities while playing soccer (production paradigm). Since some results from previous studies suggest an influence of age on the estimation, as well as production competence, the present study aimed to determine if the performances in the estimation and the production paradigm depend on age (10).

2. Methods

Twenty-five male children participated in the present study. Mean age was 12.0 years (standard deviation SD: 0.9 years) and all children were free from overt orthopedic or psychic

impairments. All participants were members of a regional soccer club and had completed at least 180 min of soccer training per week for the previous four weeks prior to the start of the study. The participants and their legal representatives gave their written informed consent to participate in the study. The study was performed in accordance with the Declaration of Helsinki and had been pre-approved by the Ethics Committee of the Leibniz University Hannover (ID 209_10_2021).

2.1. Procedure

The participants first performed cognitive tests and then participated in two training sessions separated by one week. A flowchart on the study design is available as **Supplementary File** (Flowchart).

2.1.1. Soccer training

The children performed two 90-minute training sessions. All children played in a group with children of the same age only (11 years: $n = 9$, 12 years: $n = 7$, 13 years: $n = 9$). The training sessions were identical for all age groups. They were supervised by the same trainers, who in turn instructed the same exercises with the same settings in both training sessions. The sessions comprised of 10 tasks: Running exercises (task 1); passing, running, and scoring (task 2); passing in dynamic environments (task 3); possession play against an outnumbered team (tasks 4–6); dribbling and scoring without and with time pressure (tasks 7 & 8); free play (tasks 9 & 10).

2.1.2. Heart rate and RPE-competence

Heart rate was measured with a team system (acentas GmbH, Hoegertshausen, Germany, frequency 1 Hz). The participants wore a breast belt, which transmitted data wirelessly to a laptop computer. Markers were set to the data denoting the time-points when perceived effort was rated. Maximum HR was calculated according to a formula from Hottenrott et al. (28), which had been derived from a regression of maximum heart rates (HRmax) and RPE measures from 1,600 participants aged 10 to 70 years (intercept: 207.7, slope: 0.64). Applied to the present sample, the formula resulted in a calculated HRmax of 200.00 (SD: 0.56). If a higher HR was measured during training, the calculated value was substituted with the measured value. The individual HR data were assigned to HR zones: zone 1: ≤60%; zone 2: >60 and ≤70%; zone 3: >70 and ≤80%; zone 4: >80 and ≤90%; and zone 5: >90% of the individual HRmax). The training load of each task was evaluated with the summated HR zone method described by Edwards (16), which yields a summated HR zone score (sHRz). The durations spent in the HR zones are multiplied with the weighting factors 1–5 and then summated; that is, the duration spent in zone 1 is multiplied with the weighting factor 1 and the duration spent in zone 5 is multiplied with the weighting factor 5.

Perceived effort was rated with a modified OMNI Scale (29, 30) which is one of several scales recommended for children (31). The wording of the original OMNI Scale had been adapted for the present study: In order to focus on the rating of effort, the lowest scale value was represented by the term "gar nicht anstrengend", which is the German translation of the terms "no effort at all" and "no exertion at all". Different degrees of effort were differentiated with the terms "leicht" (translation of "easy" "light"), "mittel" ("intermediate"), "schwer" ("hard"/"heavy") and "sehr sehr schwer" ("very very hard/heavy"). These were anchor terms of a scale in a study from Baschta and Lange (32), in which 12- to 14-year-old participants were able to differentiate different degrees of exertion during a 6-min-run. For the rating, the investigators called each player to the sideline, asked for the effort, and instructed him to indicate the perceived effort by pointing on the OMNI Scale. Perceived effort was rated at the end of each training task, on average every 9.2 (SD: 1.3) minutes.

2.2. Production of intensities

All participants performed a second training session with the same contents and durations as the first session. For one participant, RPE of the second session was not recorded due to an error in documentation. Therefore, in the second training session, only his HR data were analyzed. Before each exercise started, each participant was informed about his RPE in the same task of the first session and then instructed to train with a pre-determined intensity slightly below, equal or higher than before: 64% of the effort ratings during the first session were lower than the value 5 on the OMNI-scale, which might indicate that the children predominantly exercised below the ventilatory threshold (33). In these cases, it did not seem reasonable to instruct lower intensities. Therefore, on average, each child was instructed at a higher intensity in training session 2 than in training session 1 (mean difference of OMNI-scale values: 1.76, SD: 0.48, range: −2–+4). At the end of each training task, each participant again rated the perceived effort.

2.3. Cognitive assessment

Two non-verbal neuropsychological tests (paper-pencil-tests) and one questionnaire were applied. The tests used were the same tests that proved correlations between cognitive performance factors and the perception of effort in adults and adolescents in previous studies (12, 15, 34).

The Number-Connection-Test measures the speed of information processing. Within 30s, the participants have to connect on a DIN A4 sheet of paper numbers in ascending order as quickly as possible. Consecutive numbers are located directly above, below, to the left, to the right, or at a diagonal position to each other. Performance time is transformed into a measure that informs about how many Bits can be cognitively processed within one second (Bit/s). The outcome is related to fluid intelligence and correlates with medium-to-large effects with the outcome of intelligence tests (35, 36). Furthermore, information processing is one of four core areas within a framework on

executive control described by Anderson (14) from a developmental perspective.

The Five-Point-Test provides measures for spontaneous and reactive flexibility. Within 3 min, the participants have to produce as many unique designs as possible while avoiding repetitions. A design is produced by connecting two to five dots, which are preprinted in a rectangle. A sheet of paper (DIN A4) contains forty rectangles, and the participants worked on one to two sheets of paper depending on their performance speed. The present study applied the HAMASH-version published by Haid et al. (37). The number of unique designs reflects spontaneous flexibility; the number of repeated designs reflects cognitive flexibility emerging from inhibition, i.e., reactive flexibility (38, 39). Both measures are compared with normative data of 11–14 year old children (40, 41). Fluency is also considered to be part of the domain of information processing within the framework of Anderson (14) on executive control.

Furthermore, the participants provided a self-report on executive functions by answering the BRIEF-questionnaire (Behavior Rating of Executive Functioning for children). In the questionnaire, they were asked about the occurrence of various behavioral aspects in everyday life during the past months. From the responses, a behavioral regulation index was calculated as a measure for the self-view on the "inhibition of thoughts and actions, flexibility in shifting the problem-solving set, regulation of emotional responses, and monitoring one's actions" (42), p. 23). A German version of the questionnaire and normative data are provided by Drechsler and Steinhausen (43).

2.4. Statistics

The assumption of normality was tested with the Shapiro–Wilk-Test and the assumption of variance homogeneity was tested using the Levene's test. Any violations to the assumptions of normality or homogeneity are mentioned specifically in the results section.

The results of the Number-Connection-Test and the BRIEF-questionnaire were compared with data from normative samples using a one-sample *t*-test (36, 43). The data from the Five Point Test was compared with data from thirty 11–14 year old participants provided by Risser and Andrikopoulos (40) published in Spreen & Strauss (41) by an independent samples *t*-test (**Section 3.1**).

The intensity distributions were analyzed in **Section 3.2** by a one-way ANOVA with the within-subject factor heart rate zone. Due to the significance of Mauchly's test, which indicates a violation of the sphericity assumption, the *p*-level was corrected according to the Huyhn-Feldt-procedure. Post-hoc comparisons were performed using a Tukey's post-hoc test.

Relationships between RPE, cHR, and sHRz were analyzed in **Section 3.3** with a hierarchical linear model (HLM) with "participant" as a random level 2 predictor and cHR as well as sHRz as fixed level 1 predictors. The restricted maximum likelihood method was chosen as the estimation method and the degrees of freedom were calculated with the Kenward-Roger-Approximation. It was controlled that the Akaike information criterion (AIC) of each HLM was higher than the AIC of a null model with "participant" as a single predictor. Partial correlations between RPE and cHR as well as RPE and sHRz were calculated for each participant by individual regression analyses. Z-transformed semi-partial correlation coefficients were used in the following analyses (44). The regression equations from the individual regression analyses allowed calculations of prediction values for RPE from cHR and sHRz in training session 2.

The hypothesis that the RPE-variance explained by cHR is related to the results of the cognitive performance tests and the BRIEF-questionnaire was tested with confirmatory factor analysis. In the confirmatory factor analysis, this hypothesis is the global null hypothesis. Because the model is confirmed by an insignificant result, it is reasonable to assess model validity with further descriptive measures. According to Hu and Bentler (45), the following indices and suggested cut-off values were defined: root mean square error of approximation (RMSEA, ≤ 0.06), comparative fit index (CFI, ≥ 0.95), Tucker Lewis Index (TLI, ≥ 0.95) and standardized root mean square residuals (SRM, ≤ 0.08). Furthermore, the hypothesis is confirmed if the factor loadings of each cognitive variable as well as of cHR are significant. If sHRz is added to the model, its factor loadings should not be significant.

The data from training session 2 were analyzed in **Section 3.4** using repeated-measures ANOVAs. One ANOVA was performed with the within-subject factor RPE measure (rating session 1, instruction session 2, prediction session 2, rating session 2). Two separate ANOVAs were calculated for cHR and sHRz with the within-subject-factor session (1 vs. 2).

In **Section 3.5**, age group effects for the estimation competence were analyzed using a one-way ANOVA with the between-subject factor age and the dependent variable factor score, which was derived from the above-described confirmatory factor analysis. Age group effects for the production competence were analyzed by entering age as a between-subject factor to the respective ANOVAs.

3. Results

3.1. Cognitive performance and self-report

According to the results of the number connection test, the children were able to cognitively process on average 1.83 Bits per second (SD: 0.55, 95% CI: 0.45). The children performed about half a standard deviation worse (mean z: −0.55, SD: 1.22, 95% CI: 1.01) compared to the mean of the normative sample [mean z: 0, SD: 1, $t(24) = -2.24$, $p = 0.035$, $d = -0.45$]. In the Five-Point Test, the participants produced 32.36 (SD: 7.67, 95% CI: 6.33) unique designs. Compared to normative data (mean 29.5, SD: 7.77, $n = 30$) of 11–14 year old participants, the performance of the present sample was not significantly different [$t(53) = 1.37$, $p = 0.177$, $d = 0.37$]. The participants produced 1.80 (SD: 1.71, 95% CI: 1.41) perseverations. Again, there was not a significant

difference compared to normative data [mean: 1.27, SD: 1.76, $t(53) = 1.13$, $p = 0.265$, $d = 0.31$]. The mean behavioral regulation index from the BRIEF questionnaire was 63.48 (SD: 7.82, 95% CI: 6.46). Compared with data from the normative sample, the participants of the present study rated their behavioral control during daily activities lower than age-matched controls [$t(24) = 2.42$, $p = 0.023$, $d = 0.48$].

3.2. Exercise intensities in training session 1

The children reached an average HRpeak of 192.96 (SD: 8.99, 95% CI: 7.26) beats per minute, which was significantly lower than the calculated HRmax of 200.00 [SD: 0.56, 95% CI: 0.45, $t(25) = -4.05$, $p < 0.001$, $d = -0.79$]. The HRpeak of six children (mean: 205.17, SD: 4.31, 95% CI: 9.04) was higher than the calculated HRmax. Therefore, HRpeak was used to calculate their heart rate zones.

Figure 1 illustrates the temporal distribution of the training in relation to the heart rate zones in training session 1. The children trained for the largest amount of time with submaximal intensities between 60% and 80% of the HRmax. The participants trained significantly longer in zones 2 and 3 than in the other zones [$F(4.96) = 24.90$, $p < 0.001$, $\eta^2_p = 0.51$, post-hoc test: at least $p < 0.05$]. The least amount of time was trained with more than 90% of HRmax (all $p < 0.05$). The time trained at the highest intensity was still significantly different from zero [$t(24) = 3.72$, $p = 0.001$, $d = 0.74$].

3.3. RPE-competencies in training session 1

The children rated perceived effort 10 times every 9.2 min (SD: 1.3). At the time of a rating, the cHR was measured. The sHRz was calculated for the time interval that had passed since the last rating. To analyze whether the ratings of perceived effort are related to the heart rate data, a hierarchical linear model was calculated with RPE as the criterion variable and cHR, sHRz, and "participant" as predictor variables. The model predictions are plotted against the measured RPE values in Figure 2. All predictors were significant (each $p < 0.001$). As indicated by the conditional R^2, the predictors explained 45% of the RPE variance together (95% CI: 0.18). As indicated by the marginal R^2, cHR, and sHRz explained 27% of the variance together (95% CI: 0.19). The significance of the fixed predictors confirms a two-component structure of RPE which has been previously reported on adults in the literature. The significance of the random predictor confirms that the relationships between RPE and heart rate data differed between the participants. Therefore, semi-partial correlation coefficients for cHR and sHRz were calculated for each participant by individual regression analyses. The analyses yielded median semi-partial correlation coefficients of $r_s = 0.43$ (interquartile ranges—IQR: 0.59, mean: 0.37, 95% CI: 0.27) for cHR and $r_s = 0.45$ (IQR: 0.24, mean: 0.43, 95% CI: 0.18) for sHRz. The correlation coefficients were transformed with Fisher's z-transformation for the following analyses.

A confirmatory factor analysis was performed to test the hypothesis that the results from the cognitive performance tests and the BRIEF questionnaire are related to the variance component of RPE exclusively explained by cHR. The cognitive measures and the z-transformed correlation coefficient of cHR were included in the analysis. Perseveration was not included due to violations of the assumption of normality.

The χ^2-Test of the factor model was not significant [$\chi^2_{(2)} = 1.87$, $p = 0.392$]; thus, the global null hypothesis assuming the described relationship was not rejected. The descriptive measures were in the ranges defined *a priori* (CFI = 1.00, TLI =1.03, RMSEA ≤0.01, SRMR = 0.05). Moreover, the factor loadings of all variables were significant (z-transformed r_s of cHR: $p = 0.039$, z-standardized factor loading: 2.06; Bit/s: $p = 0.002$, z-standardized factor loading: 3.14; unique designs: $p = 0.006$, z-standardized factor loading: 2.76; BRIEF: $p < 0.001$, z-standardized factor loading: 3.57). Introducing the z-transformed correlation coefficient of sHRz to the factor model yielded an insignificant factor loading for this variable ($p = 0.552$, z-standardized factor loading: −0.60).

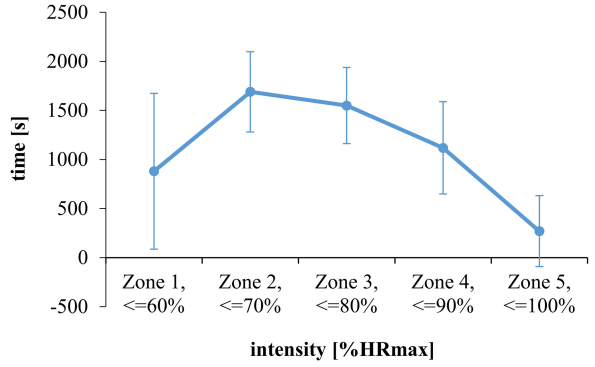

FIGURE 1
Training volume at five different heart rate zones during training session 1 (estimation task). Data are illustrated as inter-individual means and standard deviations.

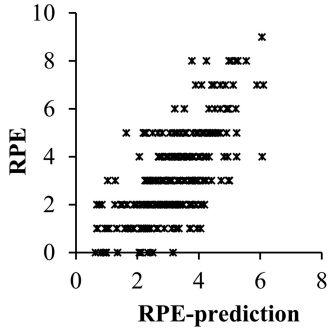

FIGURE 2
Plots of RPE and RPE-prediction from the hierarchical linear model (HLM) with current heart rate and the summated heart rate zone score in training session 1 as level 1 predictors and participant as level 2 predictor.

3.4. Production of intensities in training session 2

In the second training session, the participants performed the same training tasks as in session 1, but now received instructions concerning the production of training intensities. The instructions were on average 1.76 (SD: 0.49, 95% CI: 0.40) rating scale values higher than in the first training session. Figure 3 contrasts the subjective ratings from training session 1 and the rated, instructed as well as predicted RPE in training session 2. The prediction for RPE was calculated for each participant with his regression equation from training session 1 describing the relationship between RPE, cHR, and sHRz. Inserting the cHR- and sHRz-data from training session 2 into the regression equations yielded predictions for RPE in training session 2. An ANOVA revealed significant differences between the four variables [$F(3.69) = 62.22$, $p < 0.001$, $\eta_p^2 = 0.73$]. Post-hoc tests confirmed that the participants rated effort significantly higher in training session 2 than in session 1 ($d = 1.22$, $p < 0.001$) and higher than predicted from the heart rate data ($d = 1.19$, $p < 0.001$).

The RPE prediction for session 2 did not differ significantly from RPE in training session 1 ($d = -0.19$, $p = 0.780$). Accordingly, neither cHR nor sHRz differed significantly between both sessions (Figure 4, cHR: $F(1.24) = 1.87$, $p = 0.184$, $\eta_p^2 = 0.07$; sHRz: $F(1.24) = 0.28$, $p = 0.605$, $\eta_p^2 = 0.01$).

3.5. Effects of age on estimation and production performance

If the competencies for estimating and producing intensities are related to maturation, it is expected that older children have higher estimation- and production competencies than younger children. To investigate the influence of age on the estimation competence, the individual factor scores from the factor analysis

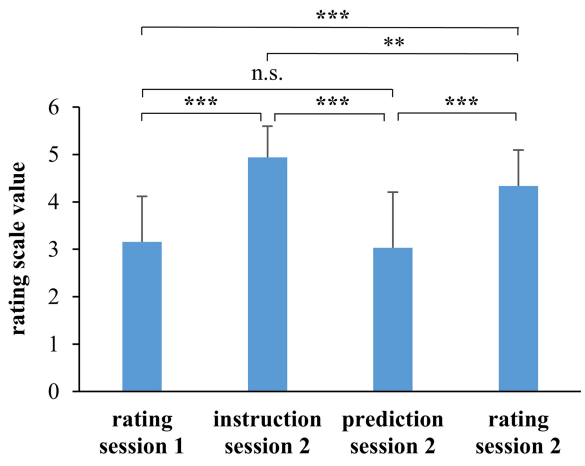

FIGURE 3
Mean scale values for the instructed, predicted, and rated intensities in training session 2 and rated intensity in training session 1. n.s., not significant. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

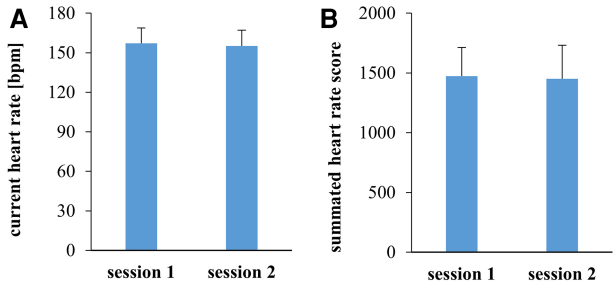

FIGURE 4
Current heart rate at the time when the perception of effort was rated (A) and the summated heart rate zone score (B) in training sessions 1 and 2. Data are illustrated as between-subject means and standard deviations.

in Section 3.3 were compared across the three age groups of the present study. As shown by Figure 5A and statistically confirmed by ANOVA, the factor scores increase significantly with age [$F(2.22) = 4.07$, $p = 0.031$, $\eta_p^2 = 0.27$]. In the post-hoc analysis, thirteen-year-old children had significantly higher factor scores than eleven-year-old children ($d = 1.26$, $p = 0.024$). Twelve-year-old children did not differ significantly from eleven-year-old ($d = 0.57$, $p = 0.421$) or thirteen-year-old-children ($d = -0.95$, $p = 0.363$).

Effects of age regarding the production performance in training session 2 were analyzed by comparing the instructed, the predicted, and the rated effort of session 2 between age groups. The data were normalized by subtracting the ratings from session 1. This normalization was necessary to meet the homogeneity assumption, which is violated when considering the non-normalized data. The results are illustrated in Figure 5B. The ANOVA yielded a significant effect of age [$F(2.21) = 4.08$, $p = 0.032$, $\eta_p^2 = 0.28$] as well as a significant interaction measure × age [$F(4.42) = 3.50$, $p = 0.015$, $\eta_p^2 = 0.25$]. Post-hoc comparisons confirmed significantly lower RPE 2-values of the thirteen-year-old than the eleven-year-old children ($d = -1.69$, $p = 0.027$). Other group differences were not significant.

4. Discussion

The present study investigated children's competencies to rate perceived effort and produce predetermined intensities during soccer training. A review by Groslambert and Mahon (10) concluded that children aged 8–12 years can differentiate only four intensities. Recently, Kasai et al. (23) concluded that children are capable of assessing effort in a more fine-grained manner, provided that a child-appropriate effort scale (e.g., the OMNI-scale) is used and the examination is conducted in a controlled laboratory setting with an incremental exercise protocol. Such procedures might simplify the rating of perceived effort, because the load increases proportionally with the test duration, making future loads predictable. The present study investigated children during soccer training, in which they cannot base their ratings on the expectation of increasing load profiles, because intensities vary over time (the load profiles over

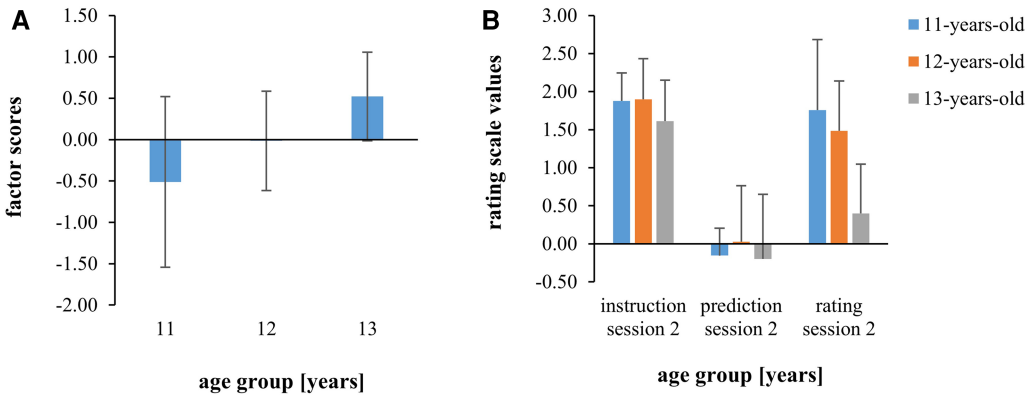

FIGURE 5
Scores from the factor analysis differentiated by age groups (A) mean scale values for the instructed, predicted, and rated intensities in training session 2 normalized by subtraction on rating scale values from training session 1 differentiated by age group (B) shown are between-subject means and standard deviations.

time can be assessed from the Data Sheet). The hierarchical linear regression analysis on the data of the first training session shows high associations between the subjective and the objective load measures (**Section 3.3**). From these results, it can be concluded, that children aged 11–13 years are able to rate perceived effort during soccer training.

Two heart rate measures explain independent portions of the RPE variance. cHR represents a punctual measure and reflects the current physiological strain. sHRz is based on the summation of all heart rate measures during a training task and thus reflects the cumulative training load of this task. This differential result might contribute to the elucidation of a conceptual discourse that reveals itself in terms of terminology. It is highly debated whether "rating of perceived effort" or "rating of perceived exertion" denote the same or different phenomena and whether one term is more adequate than the other in describing the subjective perception during exercising. According to Abbiss et al. (13), effort refers to "the amount of … energy given to a task" and exertion to "the strain experienced during a physical task". Following this view, the RPE component explained by cHR might characterize what is described by the term effort, and the RPE component explained by sHRz might reflect exertion.

Although the results of training session 1 show that children of this age can already make reasonable statements about their perceived effort and exertion, the mean correlation coefficient between cHR and RPE (0.43) was lower than in studies with adult soccer players [0.71 and 0.61 (12, 15)]. In contrast, the mean correlation coefficient between sHRz and RPE (0.45) was comparable to those of adults [0.42 (15)]. The previously reported differences between children and adults in RPE competence (10, 31) might thus be attributed to the variance component of RPE that is explained by the current heart rate. In accordance with the above reasoning, this component is likely related to the perception of effort. Age was also a significant factor in the present study. The thirteen-year-old children achieved higher factor scores in the factor analysis than the eleven-year-old children. This shows that the competence subsumed in the factor is more pronounced in thirteen-year-olds than in eleven-year-olds. The lower divergence between measured and predicted RPE in thirteen- compared to eleven-year-old children in training session 2 also reflects better estimation performance in the older age group.

The results of the first training session also point to inter-individual differences regarding the RPE-competence. It is assumed that the RPE-competence is related to cognitive abilities that develop during childhood and adolescence. The result of the confirmatory factor analysis supports this view and the more specific hypothesis of the present study because it shows that the performances in the number connection test, the five-point test as well as the results from the BRIEF questionnaire are related to the RPE component exclusively explained by cHR (12, 15, 34). Noteworthy is the outcome of the BRIEF questionnaire. Higher RPE competencies, faster processing speed, and spontaneous flexibility were associated with higher scores in the behavioral regulation index. A similar result has been reported by Schmitz and Sommer (15) for adult soccer players. Higher scores indicate that these participants feel less inhibitory and emotional control, less flexibility, and lower performance regarding the monitoring of their actions in their daily life. Since the questionnaire captures the own view of participants, these results might indicate that participants with higher performance regarding RPE and information processing have a more critical view on their executive control.

The second part of the study investigated whether children are able to produce instructed intensities during soccer training. A second training session was performed similar to the first session, with the difference that the participants were instructed to reach predefined intensities. Since the participants had rated effort comparably low in the first session, it was necessary to instruct on average higher intensities in the second training session. The children indeed rated effort significantly higher in the second than in the first session (**Figure 4**). However, none of the heart rate measures reflect an intensity increase. Thus, the children perceived a higher effort, but this effort was not reflected by the

measured physiological parameters. The effect was somewhat less pronounced in the 13-year-olds, although no changes in heart rate parameters were measurable in them either. In a study from Eston and Lamb (46), children realized lower intensities when instructed to produce scores of 3, 5, and 7 on the RPE scale compared with a previous situation in which they self-rated intensities as 3, 5, and 7 on the RPE scale. The same might have happened in the present study, with a higher RPE in session 2 resulting in nearly similar heart rates compared to session 1.

A systematic literature review suggested that children perform worse in the production compared to the estimation paradigm. However, only a few studies directly compared estimation and production performance (23, 31). Lamb (5) argued that they might not be compared as the underlying competences differ too much. Other criticisms concerned differences between tasks (one often continuous and the other intermitted) or the statistical analyses (5, 31). In the present study, the exercise protocols of training session 1 and 2 were similar, but different statistical analyses had to be performed. Therefore, comparisons can only be made on an argumentative level. The results indicate that estimation and production performance diverged in the present study. Though the children were competent in rating perceived effort, they failed to produce instructed intensities during the second soccer training. This might indicate that the production of intensities requires further competencies beyond the RPE competence which are not yet sufficiently developed at this age. As will be discussed in the following, the production competence appears to depend on intrinsic factors. Moreover, production performance may also depend on environmental constraints like the presence of other individuals.

The competence for regulating exercise intensity seems dependent on age. Menting et al. (47) reported that children aged 10–14 years regulate their running speed during an endurance task in a goal-directed way, whereas younger children apply all-out pacing, which means that they start very fast and then decrease their running speed over time. The behavior of older children still differs from that of adults. Another moderating factor for intensity regulation might be cognitive development. By controlling for age, Micklewright et al. (48) showed that children with more advanced cognitive development realize a more adapted pacing strategy, i.e., a more adequate intensity regulation, than children with lower cognitive development. According to Holgado and Sanabria (49) as well as Sakalidis et al. (50), executive functions might again play an essential role. Since estimation and production performance sometimes differ, further executive functions may be relevant for the regulation of intensities. From a developmental perspective, working memory, action monitoring, affective decision-making, and goal setting might be candidates as they are not fully developed until adulthood (51, 52). As argued by Hyland-Moks et al. (53) as well as Sakalidis et al. (50), it is plausible to assume that these functions are involved in the regulation of exercise intensities. Another explanatory approach is the probable influence of environmental factors, which seem to change with age. Performing sports together with other people seems to negatively affect intensity regulation in children but positively affect intensity regulation in adults (47). A similar effect has been found in individuals with intellectual disabilities who have less developed executive functions compared to individuals without intellectual disabilities (54). Since soccer is a team sport, these findings may explain why children in the present study were not able to change their intensities in the second training session.

Several limitations of the present study need to be addressed. Edward's heart rate zone method requires determination of HRmax. Since the testing effort for each child in the present study was already high, the measurement of HRmax was omitted. Instead, HRmax was approximated with a formula, which is recommended in cases when HRmax cannot be measured with appropriate tests (23). Nevertheless, measuring HRmax is recommended for future studies, for example, with a 20 m shuttle run test (6), which is a widely used test in soccer.

As an alternative to the measure used in the present study, other measures of cumulative exercise intensity might be considered in both research and practical applications. Although several studies reported large correlations between sHRz and RPE in children and adolescents (17–20, 22, 55), it can be questioned whether the heart rate zones should have the same thresholds for all age groups. To individualize thresholds, other physiological parameters besides HRmax might be used. For example, Lucia et al. defined three heart rate zones in relation to the ventilatory thresholds (56). Impellizzeri et al. (55) found larger correlations between RPE and Lucia's zone score than between RPE and Edward's zone score in adolescent soccer players ($r = 0.70$ vs. $r = 0.64$). Nonetheless, sHRz is useful when no other physiological parameters can be collected, which is usually the case in amateur sports.

It is shown that the RPE-competence is related to the cognitive development of the participants. Thus, RPE-scales should be individually validated by setting RPE in relation to heart rate measures. The present study results suggest that cHR as well as sHRz should be determined, as they independently explain variance in RPE-competence. The children of the present study were able to use the modified OMNI scale to rate perceived effort in a field situation. A study from Eston et al. (57) suggests that children's perceived effort increases exponentially with linearly increasing load. Therefore, a curvilinear rating scale such as the Eston-Parfitt (E-P) scale might be more appropriate in the work with children. Furthermore, as repeated use of the scales increases the reliability of the measurements, adequate familiarization phases should be realized when new scales are introduced (8, 26). Finally, coaches must be aware of the responsibility in dealing with intensity instructions. First, intensity instructions might have an impact on children's perceived effort. Second, as long as it is not clear whether children can produce prescribed intensities in complex sports situations, coaches might carefully reflect on whether to provide intensity instructions during a given task or not. Which factors prevent or affect the production of intensities should be investigated in further studies.

5. Conclusion

The results from the present study show that children aged 11–13 are able to rate perceived effort during soccer training.

Correlations of two different heart rate-based measures with the rating score confirm an assumed multi-component structure of RPE. The competence to rate perceived effort seems to be less developed in younger compared to older children and compared to adults. It was confirmed that the rating performance is related to the performance in cognitive tests supporting the hypothesis that RPE competencies depend on cognitive development. In a second training session, the children were unable to change their intensities in response to instructions. Future research needs to identify the underlying factors of this competence.

Data availability statement

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

Ethics statement

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

Author contributions

GS and MR designed the study. MR designed the training sessions and recorded the data. GS and MR analysed the data. GS wrote the first draft of the manuscript reviewed by MR. GS supervised the project. 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/fspor.2023.1251585/full#supplementary-material

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Effect of changes in the net height, court size, and serve limitations on technical-tactical, physical, and psychological aspects of U-14 female volleyball matches

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Introduction: The objective was to analyze the effect of a reduction of the net height and the court size and serve limitations on the technical-tactical actions, physical actions, and psychological aspects in youth volleyball players.

Methods: The sample was 29 under-14 female volleyball players (three regional club teams). A quasi-experimental design was implemented to assess the effect of modification in three tournaments. The independent variables were: a) official rules tournament (no changes in the rules), b) Experimental Tournament 1 (reduction in the net height from 2.10 m to 2 m, no jump serves, and a maximum of two serves per player and rotation), and c) Experimental Tournament 2 (reduction in net height from 2.10 m to 2 m, reduction in court size from 9 × 9 m to 8 × 8 m, no jump serves, and a maximum of two serves per player and rotation). The dependent variables were: ball contact done (type), quality and efficacy of the technical actions, team game phases occurrence, quality and efficacy, continuity index, number of jumps, player's jump load in the take-off and landing, number of hits, average heart rate, Rate of Perceived Effort, time between ball contacts, serve velocity, perceived individual and collective self-efficacy, perceived enjoyment, and perceived satisfaction.

Results: Experimental Tournament 1 involved an increase in the efficacy of serves and a decrease in the efficacy of side-out phases. The imbalance between serve and reception did not impact game continuity but reduced the attack and blocks. Experimental Tournament 2 involved a decrease in the efficacy of serves and an increase in the efficacy of side-out phases. The balance between serve and reception increased reception efficacy, the occurrence of attacks and blocks, game continuity, and players' effort. players' effort.

Discussion: Scaling the net and court and adapting the serve rules (Experimental Tournament 2) resulted in game dynamics for these U-12 teams that were more similar to those of posterior stages of player through the balance between serve and reception and the adaptation of the net height and court size.

KEYWORDS

team sport, youth, constraints, scaling, development, competition rules

Introduction

Volleyball is a net sport and team sport in which players cannot catch the ball. This characteristic makes the learning process difficult due to the requirement of physical and motor skills that players must have to volley the ball. Rules allow teams to make three contacts with the ball. Teams use these three contacts to carry out a cyclical sequence of actions to control and send the ball to the opponent's court with the intent of obtaining a point by making the ball contact the opponent's court. The first action of a rally is the serve which sends the ball to the opponent's court (reception). The first team's contact attempts to control the ball sent by the opponent. The second contact attempts to create the best conditions to send the ball to the opponent's court (set). Finally, the third contact tries to put the ball in contact with the opponent's court (attack). The other team attempts to neutralize the opponent's attack near the net by making a block, which does not count in the cycle of three contacts allowed per team. After that, the team will try to neutralize the attack (defense) and start the cycle again, building their offense. The play continues with this cycle until one of the teams gets a point. Through the developmental process, the goal of training and competition is to provide players with appropriate experiences for their level of maturity and skill to achieve the purpose of the game. Competition rules for each age group establish the reference conditions that players will have in their games. The manipulation of the game rules throughout the players' development seeks to increase children's participation through actions that are appropriate to their learning and physical, technical, and psychological characteristics (Bunker and Thorpe, 1982; Kirk and MacPhail, 2002; Buszard et al., 2016). In volleyball, federations or school organizations establish the competition formats and rules adapted to the players' development. In the 1960s, an adaptation of volleyball was developed for younger age groups, called mini volley (Baacke, 1975). This adapted sport involves scaling the structural aspect of the game, like the number of players, net height, ball size, and court size (Buszard et al., 2016). For older players (U-12 and older), volleyball is played with similar rules to adults, except that the net height progresses until the adult height is reached by U-16 players. The evolution of the net height and other rule adaptations, such as the use of the libero (player who specializes in defense) and serve limitations (e.g., no jump serve allowed), change for each country or region. Currently, there is no evidence of the adequacy and impact of these rules for each age group. The influence of these rules on the development of the youth player is unknown.

There are studies that show the effect of the manipulation of different constraints (Newell, 1986) on the game during training: type of ball, court size, number of players, ball retention, etc. (i.e., Castro et al., 2022; Halouani et al., 2023). These studies had the goal of providing information to physical education teachers and volleyball coaches about the manipulation of different task constraints. For example, the manipulation of the net height affects the trajectory of the ball which impacts the time that players have to intercept the ball (Palao and Guzman, 2008). The net height should be established according to the anthropometric and physical characteristics of players. An increase in the net height increases the ball parabola and provides players with more time to the intercept ball. This, in theory, improves the players' chances of intercepting the movement, the quality of the reception and defense actions, and the continuity of the game. However, the actions of serve and spike, in which players try to put the ball in contact with the court, are affected. A higher net changes the trajectory of the serve and attack, and it can impact the speed of these movements. The manipulation of the court size affects the area that players have to cover and their ability to intercept the ball. An increase in the court size made it more difficult for players to intercept the ball and decreased the quality of the first team's ball contact. The reduction of the court area limits the ball trajectories, reduces ball speed, and increases the chances of intercepting the ball (Ronglan and Grydeland, 2006; Rodrigues et al., 2022). The specific effect of court manipulation changes for each court size (Rocha et al., 2020a,b; Rodrigues et al., 2022). The changes of the court size are influenced by the number of players: m^2 per player (Halouani et al., 2023). The interaction of the manipulation of net height and court size on small-side games results in different changes in the game's continuity, quality, and efficacy of the technical-tactical actions. These manipulations could change the movements, physical actions, and other aspects that are impacted by the way players execute their actions, such as motivation or self-efficacy. An increase in the game's continuity and the efficacy of the terminal actions (spike and block) increase the motivation of volleyball players (García-de-Alcaraz et al., 2022). In the review carried out, no evidence was found regarding the impact of the serve and spike with different net heights and court changes for younger players in competition. The studies that were found analyzed the effect of net height and court size manipulation on small-sided games.

This study tries to provide evidence regarding the possibility of adapting the rules to the players' needs during the development process. The low number of experimental studies about the progression of the game rules' adaptation makes it difficult to know if the current competition format for each age group is the most adequate option or not. The information currently available in other sports shows that a progressive adaptation of the normative competition could result in qualitative and quantitative improvements of the realization of the technical-tactical actions in competition (i.e., Lapresa et al., 2010; García-Angulo et al., 2020a,b; Gimenez-Egido et al., 2020; Ortega-Toro et al., 2021). Knowing the impact of the manipulation of the net height and court size could contribute to the development of competition rules that allow for better development of youth volleyball players according to their maturity and skills. Knowledge of the effect of these rule changes will allow various stakeholders to consider the possibility of developing different proposals for competition rules for youth volleyball players. Using the evolution of the players through their developmental process as a reference (i.e., García-de-Alcaraz et al., 2017; Echeverria et al., 2019), the experimental hypothesis is that scaling the net and court and adapting the serve rules would increase the efficacy and quality of the technical and tactical actions and players' participation in the game. The objective of this study was to analyze the effect of a reduction of the net height (from 2.10 to 2 m) and the court size (from 9×9 m to 8×8 m) and serve limitations on the technical-tactical actions, physical actions, and psychological aspects in youth volleyball players.

Materials and methods

Participants

The sample was 29 under-14 female volleyball players belonging to three amateur teams from the U-14 age group (regional club competition). The characteristics of the players were the following: average age of 13.4 ± 0.68 years; average height of 1.63 ± 0.96 m; average weight of 55.5 ± 7.9 kg; 2.85 ± 0.31 of average training sessions per week; 1.37 ± 0.44 of average hours of session time; and 3.21 ± 0.85 years of experience. All players in the study had reached puberty by the moment of participation in the study. Guardians of the players were informed of the study and provided written consent. Players played three tournaments using three competition formats (official rules, modified rules option #1, and modified rules option #2). A total of 5,315 ball actions done by the players in nine matches were analyzed. The study was approved by the University Ethics Committee of the research group that carried out the study (ID 1944/2018).

Design and variables

A quasi-experimental design was implemented to assess the effect of modification in: the height of the net (2.10–2.00 m), type of serve (no jump serves were allowed), limitations on total consecutive serves by players (maximum of two serves per player and rotation), and court size (9 × 9 m to 8 × 8 m). The independent variable was the game format (rules). There were three levels: official rules (Control Tournament) and modified rules (Tournaments #1 and #2). The differences between the official and modified rules were the following: net height (2.10 m vs. 2.00 m), size of the field (9 × 9 m vs. 8 × 8 m), and limitations on the serves done by players (unlimited vs. maximum of two consecutive serves in each rotation) and type of serve (jump serves were not allowed). When the limit of serves was reached, the serving team rotated. Table 1 shows the rules that were used in the different competition formats. The first tournament was played according to the official state rules for the U-14 competitions established by the Spanish National Federation. In the second and third tournaments, a modification of the official U-14 volleyball rules was implemented. The players studied played the tournaments with their usual teams.

The dependent variables were:

a) Ball contacts done (occurrence of serves, receptions, sets, attacks, blocks, and defenses);
b) Quality of the technical actions (scale 0–5). The quality of the technical actions was assessed according to the way of execution of the players' actions (Table 2). Each ball action had a quality score according to the aspects of the execution that were done properly (scale 0–5, where 0 points involved that no aspects were done properly and 5 points that all aspects were done properly);
c) Efficacy of the technical actions (scale 0 to 3–4). The efficacy of the technical actions was established according to the effect of the action on the rally (scale 0 to 3–4), in which 0 was an error, 1–3 was a continuity that allows the opponents or the own team to play the ball (not limit attack, limit attack, and does not allow to attack, 1, 2, and 3 respectively) and 4 was a point. For reception, set, and defense, a scale of 0–3 was used because these actions do not allow to get a point (continuity or preparation actions). For serve, attack, and block (terminal actions), a scale of 0 to 4 was used. The efficacy scale was developed by Coleman et al. (1969) and adapted and validated by Palao et al. (2015);
d) Coefficient efficacy (coefficient −1 to 1). A coefficient efficacy was calculated with the efficacy of each variable using the formula: occurrence of the highest efficacy minus the occurrence of the worst efficacy divided by the occurrence of the action;
e) Team game phases (serve phase, phases done by the team in reception-set-attack, and phases done by the team in defense-set-counter attack phase);
f) Team game phases efficacy (scale 0–4). The efficacy of the technical actions was established according to the effect of the action on the rally (scale 0–4), in which 0 was an error, 1–3 was a continuity that allows the opponents or the own team to play the ball (not limit attack, limit attack, and does not allow to attack, 1, 2, and 3 respectively) and 4 was a point;
g) Team game phases quality (scale 0–6). The quality of the team game phases was assessed according to players' position in the court in the phase. Each phase had a quality score according to the players that were in the position established in the phases of reception, in the initial position of defense and in the final defense position (scale 0 to, where 0 points involved that no players were in the proper position and 6 points that all players were in their established positions);
h) Continuity index (occurrence of rallies that involved continuity and percentage). The continuity index was established using the rallies per play (the number of times that the ball passed over the net);
i) Number of jumps (occurrence);
j) Player's jump load in the take-off and landing (G). The player jump load was assessed with a 3D gyroscope that players wore on their backs (WIMU, Hudl, Chicago, USA);
k) Number of hits (occurrence);
l) Average heart rate in each rally (beats per minute). The heart rate for each player was measured using a chest band (Garmin band, Olathe, Kansas, USA). The average heart rate was collected at the end of each rally;
m) Rate of Perceived Effort (scale 1–10). The rate of Perceived Exertion was collected at the end of each match using a color pictorial scale of 1–10 (adapted from Groslambert et al., 2001);
n) Time between ball contacts (seconds);
o) Serve velocity (km/h). The serve speed was calculated using two radar devices (Pocket Radar, Santa Rosa, California, USA) located behind the serve zones (peak speed);
p) Perceived individual and collective self-efficacy (scale 0–140). The individual-specific self-efficacy and collective self-efficacy were assessed using the "Questionnaire of specific self-efficacy and collective self-efficacy in volleyball" (adapted from Ryckman et al., 1982; Godoy, 1992). The "Questionnaire of Specific Self-efficacy and Collective Self-Efficacy in Volleyball" had 32 closed questions (10-item Likert scale) related to individual and collective self-efficacy (16

TABLE 1 Description of the rules implemented in the tournaments (official rules and experimental groups).

Rules	Official rules	Modified rules Tournament 1	Modified rules Tournament 2
Number of players	6 players (no libero allowed)	6 players (no libero allowed)	6 players (no libero allowed)
Net height (m)	2.10 m	2.00 m	2.00 m
Field size (m)	9 × 9 m	9 × 9 m	8 × 8 m
Ratio of m^2 per player	13.5 m^2	13.5 m^2	10.6 m^2
Serve (*n*)	No limitations number serves	Max two serves per player after that team's rotation	Max two serves per player after that team's rotation
Serve (type)	No limitations	No allowed jump serve	No allowed jump serve
Ball size (m)	0.66 m	0.66 m	0.66 m
Format	Best of 5 sets	Best of 5 sets	Best of 5 sets
Points	25 points (5th set, 15 points)	25 points (5th set, 15 points)	25 points (5th set, 15 points)
Score system	Rally score point system	Rally score point system	Rally score point system

TABLE 2 Description of criteria used to evaluate the quality of the technical actions (adapted from Palao and Hernández, 2010).

Action	Description (scale 0–5)
Serve	1. The height and trajectory of the ball tossed do not limit serve execution 2. Lower body participation of the kinetic chain of the execution (fluid, coordinative, and sequence movements) 3. Upper body participation of the kinetic chain of the execution (fluid, coordinative, and sequence movements) 4. Way in which the ball is contacted (part of the hand, the height of contact, and place of contact related to the shoulder) 5. Follow-up movement (transfer energy and incorporate into the game)
Reception & defense	1. Win the ball (the player is behind the ball before the contact because s/he perceived and intercepted the ball trajectory) 2. Orientation to the destination pass zone 3. Contact surface (first third of the forearm with arms extended, together and the same height) 4. Contact height (umbilicus height) 5. Kinetic chain (whole body participation to accelerate the ball to the destination zone)
Set	1. Win the ball (the player is behind the ball before the contact because s/he perceived and intercepted the ball trajectory) 2. Orientation to the destination pass zone 3. Contact surface (index and thumb of both hands form a triangle. Ball is contacted with the fingers and not with the palm) 4. Contact height (ball is contacted above of the line of eyes) 5. Kinetic chain (whole body participation with or without jumping to accelerate the ball to the destination zone)
Attack	1. Running approach (the approach allows player to intercept the ball without affecting her/his posterior actions) 2. Jump kinetic chain (realization of the pre-jump, body position, and sequence of the take-off) 3. Hit kinetic chain (Swing and cocking of the arm) 4. Ball contact (part of the hand, height of contact, and place of contact related to the shoulder) 5. Follow-up movement (follow-up movement of the arm swing, balance landing with two leg and arm swing in the landing)
Block	1. Appreciate and intercept ball trajectory (temporally and spatially displacement and location regarding the attack) 2. Jump kinetic chain (realization of the approach (if necessary), body position, and sequence of the take-off) 3. Arms actions (progressive action of sealing the net with the arms) 4. Ball contact and hands orientation (Both hands open, rigid, and orientated to the court) 5. Follow-up movement (follow-up movement of the arm swing and balance landing with two legs)

questions, respectively). Self-efficacy was assessed at the end of each match;

q) Perceived enjoyment (scale 1–10). Perception of players' experience was assessed after each tournament. Players were asked whether they had experienced a higher, equal, or lower self-efficacy than in the previous tournament in the different actions of the game; and

r) Perceived satisfaction (scale 1–10); the satisfaction was assessed using a scale of 0–10 at the end of each match.

Procedure

The design and validation of the "Questionnaire of specific self-efficacy and collective effectiveness in volleyball" (Supplementary Appendix 1) were done adapting a basketball survey designed and validated by García-Angulo et al. (2020a,b). The design and validation followed the Delphi method (panel of experts, college professors in Sport psychology) and an experts' evaluation. In the first phase, a panel of five expert judges participated. Two rounds were done between the panel of experts. The analysis done by the experts was qualitative. The second

phase involved doing an expert validation through four experts (Ph.D. in Kinesiology and experience in coaching volleyball) who evaluated the accuracy, precision, and wording of each section of the measuring instrument. The V of Aiken was used to calculate the content validity, obtaining minimum values of 0.95. For establishing the reliability, Test-Retest reliability was assessed with a pilot study using the test-retest technique. The pilot study was done with 21 subjects, with similar characteristics to the sample. The minimum values obtained from the intraclass correlation coefficient were 0.96 (Weir, 2005).

The data was recorded in three tournaments. The tournaments were played after the end of the official regular season. All tournaments were played in an indoor pavilion and in similar atmospheric conditions. In total, nine matches were played in the three tournaments, three matches in each tournament (two matches per team and tournament). The competition system was round robin. The order of the confrontations was the same in the different tournaments. Team followed their match routines and warm-up. The actions developed by the players were recorded with two fixed digital cameras (50 fps) from an elevated rearview (lateral and posterior). The actions were recorded and analyzed by one trained observer (Master in Sports Science with at least 2-years of experience in match analysis and volleyball). The observer was trained with the observation instrument. After the training period, inter- and intra-observer reliability were calculated (Cohen's Kappa for the nominal variables and Inter-class correlation coefficient and Pearson correlation for the continues variables). To calculate the intra-observer reliability, another researcher was used as a reference. The researcher held a sports science degree and had more than 10 years of experience in sports analytics. The reliability of the observers was measured before and after the observation. For the nominal variables, the lowest level of interobserver reliability was 0.84, and the lowest level of intra-observer reliability was 0.93 (Cohen's Kappa). For the continuous variables, the lowest level of inter-observer and intra-observer reliability was 0.96 (Inter-class correlation coefficient and Pearson correlation). Players wore an accelerometer (WIMU, Hudl, Chicago, USA) and heart rate chest band to monitor the jump load and their heart rate (Garmin band, Olathe, Kansas, USA). The radar devices were located in the middle of the baselines to record the peak speed of each serve (Pocket Radar, Santa Rosa, California, USA). Rate of Perceived effort was registered at the end of each match. Players' self-efficacy was measured at the end of each tournament (15–30 min after the last game of each tournament). In all the tournaments the same procedures were used, and the questionnaires were explained and provided by the same researcher.

Data analysis

Descriptive (means, standard deviation and percentages) and inferential statistics of the data were calculated. Data of the quality of the team game phases were expressed in the results in percentages. Data of the different self-efficacy assessed (specific self-efficacy, and collective self-efficacy) are presented in the results section on a scale 0 to 100 in order to allow the comparison of the impact of each experimental condition on self-efficacy. To assess the normality of data of the continuous and categorical variables, Kolmogorov Smirnov test and Chi square test were used, respectively. Data assumes no normal distribution which led to the use of non-parametric test. To measure the difference between the different tournaments in continuous variables, Wilcoxon test or U Mann-Whitney test were used. To measure the magnitude of the effect size, the Rank Biserial Correlation (RBC) was used, using the following classification (Coolican, 2017): minimal effect (RBC $<$ 0.10), moderate effect (0.10 $<$ RBC $<$ 0.30) and strong effect (RBC $>$ 0.50). Rank Biserial Correlation, measures the magnitude of the effect size for comparative studies, as rank correlation, when using the Wilcoxon rank test (Dominguez-Lara et al., 2019). To measure the difference between the different tournaments in categorical variables, Pearson Chi-square test was used. The effect size of these differences was established using the V of Cramer. The level of significance was set at $p < 0.05$. To measure the magnitude of the effect size the eta square (η^2) was used using the following classification (Ferguson, 2009): no effect ($\eta^2 < 0.04$), minimum effect ($0.04 < \eta^2 < 0.25$), moderate effect ($0.25 < \eta^2 < 0.64$) and strong effect ($\eta^2 > 0.64$). The statistical analysis was completed with JAMOVI statistics software (version 2.4.8).

Results

Regarding the impact of the experimental rules on the actions taken by players, each tournament resulted in specific changes in the occurrence, quality, and efficacy of the actions (Table 3). In the Control Tournament, 21.5% of the serves were done using the jump serve technique and in 58 out of 251 serves (23%) were done by players after serving more than two serves per rotation. In experimental tournaments 1 and 2, the limit of serves was reached in 10–11 out 86–88 possible situations (≅11%−12%, respectively). In Tournament 1, there were significantly fewer attacks than in Tournament 2 ($p < 0.01$, ES = 0.688), significantly fewer blocks than in both the Control Tournament ($p < 0.01$, ES = 0.696) and Tournament 2 ($p < 0.001$, ES = 0.969), significantly higher quality of the defense actions than in both the Control Tournament ($p < 0.09$, ES = 0.389) and Tournament 2 ($p < 0.05$, ES = 0.442), significantly lower block efficacy than in the Control Tournament ($p < 0.01$, ES = 0.696), a significantly higher efficacy coefficient for the serve than in Tournament 2 ($p < 0.01$, ES = 0.652), and significantly higher efficacy of the defense actions than in both the Control Tournament ($p < 0.05$, ES = 0.535) and Tournament 2 ($p < 0.05$, ES = 0.521). These differences had a medium-large effect size. In Tournament 2, there were significantly more sets than in Tournament 1 ($p < 0.01$, ES = 0.486), significantly more attacks than in both the Control Tournament ($p < 0.01$, ES = 0.588) and Tournament 1 ($p < 0.01$, ES = 0.688), significantly more blocks than in both the Control tournament ($p < 0.001$, ES = 0.920) and Tournament 1 ($p < 0.001$, ES = 0.969), significantly more defense than in Tournament 1 ($p < 0.01$, ES = 0.519), a significantly higher quality of serve execution than in the Control Tournament ($p < 0.05$, ES = 0.588), a significantly higher quality of reception execution than in both the Control Tournament ($p < 0.01$, ES = 0.498) and Tournament 1 ($p < 0.01$, ES = 0.637), a significantly lower serve efficacy than in Tournament 1 ($p < 0.01$, ES = 0.585), a significantly lower coefficient efficacy for serve than in both the

TABLE 3 Effect of rules changed on execution of the players' ball contact.

Variables	Control Tournament (TC) Net 2.10 m/ court 9 × 9 m		Tournament 1 (T1) Net 2.00 m/ court 9 × 9 m		Tournament 2 (T2) Net 2.00 m/ court 8 × 8 m		ES (RBC)		
	X	SD	*X*	SD	*X*	SD	TC-T1	TC-T2	T1-T2
Occurrence (*n*)									
Serve	9.30	5.86	9.56	5.00	10.00	5.28	n.s.	n.s.	n.s.
Reception	7.59	7.44	7.37	6.51	8.19	7.85	n.s.	n.s.	n.s.
Set	10.07	14.98	9.66	18.49	12.68	23.65	n.s.	n.s.	0.486*
Attack	10.07	8.26	9.52	7.52	13.22	11.34	n.s.	0.588**	0.688**
Block	9.15	10.55	6.67	7.73	15.56	14.70	0.696**	0.920***	0.969***
Defense	10.67	5.40	9.78	6.98	13.26	9.78	n.s.	n.s.	0.519**
Quality of execution (scale 0–5)									
Serve	3.77	0.70	3.93	0.60	4.01	0.57	n.s.	0.588*	n.s.
Reception	1.92	0.83	1.74	0.81	2.39	0.89	n.s.	0.498*	0.637**
Set	3.02	0.45	3.21	0.54	3.06	0.48	n.s.	n.s.	n.s.
Attack	2.34	0.85	2.34	0.82	2.17	0.96	n.s.	n.s.	n.s.
Block	2.06	0.36	2.24	0.60	2.21	0.51	n.s.	n.s.	n.s.
Defense	1.68	0.52	1.90	0.63	1.56	0.70	0.389#	n.s.	0.442*
Efficacy (scale 0 to 3–4)[a]									
Serve	1.97	0.42	2.41	1.16	1.74	0.50	n.s.	0.585*	n.s.
Reception	1.46	0.55	1.40	0.51	1.64	0.49	n.s.	n.s.	n.s.
Set	1.90	0.41	1.92	0.65	1.97	0.40	n.s.	n.s.	n.s.
Attack	1.98	0.63	2.06	0.73	1.90	0.59	n.s.	n.s.	n.s.
Block	1.94	0.81	1.60	0.67	1.72	0.45	0.459#	n.s.	n.s.
Defense	1.42	0.38	1.54	0.35	1.36	0.51	n.s.	n.s.	n.s.
Coefficient efficacy (scale −1 to 1)									
Serve	0.01	0.23	0.01	0.32	−0.09	0.23	n.s.	0.535*	0.652**
Reception	−0.25	0.27	−0.13	0.27	−0.03	0.24	n.s.	0.626**	n.s.
Set	0.15	0.17	0.21	0.40	0.13	0.22	n.s.	n.s.	n.s.
Attack	0.07	0.27	0.09	0.35	−0.02	0.29	n.s.	n.s.	n.s.
Block	0.06	0.17	−0.01	0.32	−0.04	0.09	n.s.	n.s.	n.s.
Defense	−0.17	0.24	−0.04	0.17	−0.20	0.31	0.535*	n.s.	0.521*

***p-value<0.001.
**p-value <0.01.
*p-value <0.05.
#p-value <0.09.
n.s., no significant; ES (RBC), effect size (Rank Biserial Correlation); TC-T1, Control Tournament vs. Tournament 1; TC-T2, Control Tournament vs. Tournament 1; T1-T2, Tournament 1 vs. Tournament 2.
[a]Scale 0–3 for the continuity actions (reception, set and defense) and scale 0–4 for the terminal actions (serve, attack and block).

Control tournament ($p < 0.05$, ES = 0.535) and Tournament 1 ($p < 0.01$, ES = 0.652), a significantly higher coefficient efficacy for reception than in the Control Tournament ($p < 0.01$, ES = 0.626), and a significantly coefficient efficacy for defense than in the Control Tournament ($p < 0.01$, ES = 0.521). These differences had a medium-large effect size.

Regarding the impact of the experimental rules on the tactical team actions (Table 4), in Tournament 1, there were significantly lower efficacy of the side-out than in Tournament 2 ($p < 0.05$, ES = 0.066) and significantly higher quality of the initial defense position than Control Tournament ($p < 0.01$, ES = 0.128). These differences had a minimum effect size. In Tournament 2, there were significantly lower efficacy of the serve phase than in both the Control Tournament ($p < 0.05$, ES = 0.091) and Tournament 1 ($p < 0.01$, ES = 0.097), a significantly higher efficacy of the side-out than in both the Control Tournament ($p < 0.05$, ES = 0.066)

TABLE 4 Effect of rules changed on tactical team actions.

	Control Tournament (TC) Net 2.10 m/ court 9 × 9 m		Tournament 1 (T1) Net 2.00 m/ court 9 × 9 m		Tournament 2 (T2) Net 2.00 m/ court 8 × 8 m		ES (RBC)		
Variables	*X*	SD	*X*	SD	*X*	SD	TC-T1	TC-T2	T1-T2
Efficacy team game phases (scale 0–4)									
Serve	2.06	1.28	2.06	1.27	1.85	1.15	n.s.	0.091*	0.097*
Reception-set-attack	1.80	1.06	1.72	1.05	1.92	1.03	n.s.	0.066*	0.109***
Defense & counterattack	1.78	1.05	1.91	1.09	1.83	1.07	n.s.	n.s.	n.s.
Quality of execution team game phases (%)									
Reception-set-attack	96.28	8.91	96.16	8.76	96.31	8.16	n.s.	n.s.	n.s.
Initial defense position	77.01	21.46	82.02	18.97	80.74	17.21	0.128**	0.077**	n.s.
Final defense position	87.87	17.41	89.38	17.32	90.14	16.43	n.s.	n.s.	n.s.
Continuity (*n*)	*N* = 1,288	79.46%	*N* = 1,266	79.62%	*N* = 1,778	84.55%	$p < 0.001$	T2 < (TC = T1)	

***p-value<0.001.
**p-value <0.01.
*p-value <0.05.
n.s., no significant; ES (RBC), effect size (Rank Biserial Correlation); TC-T1, Control Tournament vs. Tournament 1; TC-T2, Control Tournament vs. Tournament 1; T1-T2, Tournament 1 vs. Tournament 2.

and Tournament 1 ($p < 0.001$, ES = 0.109), a significantly higher quality of the initial defense position than Control Tournament ($p < 0.01$, ES = 0.077), and a significantly higher continuity than Control Tournament ($p < 0.001$). These differences had a minimum effect size.

Regarding the impact of the experimental rules on players' physical actions (Table 5), in Tournament 1, there were significantly fewer jumps than in both the Control Tournament ($p < 0.05$, ES = 0.518) and Tournament 2 ($p < 0.001$, ES = 0.958), significantly fewer hits than in Tournament 2 ($p < 0.05$, ES = 0.552), significantly higher heart rate than in both the Control Tournament ($p < 0.001$, ES = 0.134) and Tournament 2 ($p < 0.001$, ES = 0.085), significantly less time for reception than in the Control Tournament ($p < 0.05$, ES = 0.464), and significantly more time for block than in the Control Tournament ($p < 0.05$, ES = 0.481). These differences had a medium-large effect size, except for heart rate that had minimum effect size. In Tournament 2, there were significantly higher jumps than in both the Control Tournament ($p < 0.001$, ES = 0.763) and Tournament 1 ($p < 0.001$, ES = 0.958), significantly higher hits than in both the Control Tournament ($p < 0.01$, ES = 0.584) and Tournament 1 ($p < 0.05$, ES = 0.552), significantly higher heart rate than the Control Tournament ($p < 0.001$, ES = 0.055), significantly lower heart rate than Tournament 1 ($p < 0.001$, ES = 0.085), significantly less time between serve and reception than in both the Control Tournament ($p < 0.05$, ES = 0.498), significantly less time for between set and attack actions than in both the Control Tournament ($p < 0.05$, ES = 0.521) and Tournament 1 ($p < 0.05$, ES = 0.474), significantly less time for between attack and block actions than in both the Control Tournament ($p < 0.01$, ES = 0.681), and significantly lower serve speed than in the Control Tournament ($p < 0.001$, ES = 0.107). These differences had a medium-large effect size, except for heart rate that had minimum effect size. Regarding the impact of the experimental rules on the psychological aspects (Table 6), no significant differences were found between the tournament control and the experimental tournaments.

Discussion

The objective of this study was to analyze the effect of a reduction of the net height, limitations on the serve, and a reduced playing space on the technical, tactical, as well as physical actions and psychological aspects in youth female volleyball matches. Two experimental tournaments were carried out to test the implications of these rule changes on U-14 female players. Each rule change involved a different effect on the game. The reduction of the net height without changing the court size facilitated the serve action, as players increased the efficacy of their serves. Although serve speed did not increase, players in reception had less time to intercept the ball from the serve. The reduction in the reception efficacy affected the way that the offense was built and reduced the number of attacks, the side-out efficacy, and the blocks were done. The speed of the game increased. Blockers had less time to block, there were fewer blocks, and their efficacy decreased. As a result of the less-efficient attack, there was an increase in the quality of the execution and efficacy of the defense actions. The change in the game dynamics involved an increase in the players' heart rate and a reduction in the number of the players' jumps and hits. The increase in the speed of the game and in the defense participation involved players adopting better defense positions before the opponent's attack was executed (defense tactical system). The changes in the net height did not involve changes in the g-force in the take-off or the landing of the attack. The balance between serve and reception is critical to develop the offense. Throughout players' development, there is an improvement in the ability of the receivers to neutralize

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TABLE 5 Effect of rules changed on physical actions done by players.

	Control Tournament (TC) Net 2.10 m/ court 9 × 9 m		Tournament 1 (T1) Net 2.00 m/ court 9 × 9 m		Tournament 2 (T2) Net 2.00 m/ court 8 × 8 m		ES (RBC)		
Variables	*X*	SD	*X*	SD	*X*	SD	TC-T1	TC-T2	T1-T2
Jumps (*n*)	16.7	15.6	11.7	10.5	22.1	18.5	0.518*	0.763***	0.958***
Jump load (g)	3.68	0.49	3.85	0.37	3.67	0.42	n.s.	n.s.	n.s.
Landing load (g)	5.23	0.84	5.08	1.11	5.00	1.05	n.s.	n.s.	n.s.
Hits (*n*)	19.37	12.2	18.10	11.36	22.39	15.25	n.s.	0.584**	0.552*
Heart rate (bpm)	155	19.9	162	20.4	159	16.0	0.134***	0.055***	0.085***
RPE (scale 1–10)	3.21	1.57	3.31	1.81	3.77	1.58	n.s.	n.s.	n.s.
Temporality (s)									
Reception	1.32	0.13	1.27	0.10	1.29	0.09	0.464*	0.498*	n.s.
Set	1.15	0.10	1.52	0.23	1.48	0.15	n.s.	n.s.	n.s.
Attack	1.44	0.10	1.42	0.12	1.40	0.10	n.s.	0.521*	0.474*
Block	2.20	0.20	2.07	0.20	1.95	0.27	0.481*	0.681**	n.s.
Defense	1.07	0.09	1.13	0.20	1.06	0.17	n.s.	n.s.	n.s.
Serve speed (km/h)	51.4	6.52	50.2	6.53	49.5	6.20	n.s.	0.107***	n.s.

***p-value < 0.001.
**p-value < 0.01.
*p-value < 0.05.
n.s., no significant; ES (RBC), effect size (Rank Biserial Correlation); TC-T1, Control Tournament vs. Tournament 1; TC-T2, Control Tournament vs. Tournament 1; T1-T2, Tournament 1 vs. Tournament 2.

TABLE 6 Effect of rules changed on psychological aspects.

	Control Tournament (TC) Net 2.10 m/ court 9 × 9 m		Tournament 1 (T1) Net 2.00 m/ court 9 × 9 m		Tournament 2 (T2) Net 2.00 m/ court 8 × 8 m		ES (RBC)		
Variables	*X*	SD	*X*	SD	*X*	SD	TC-T1	TC-T2	T1-T2
Individual self-efficacy (%)	71.85	12.86	71.22	10.02	71.97	10.34	n.s.	n.s.	n.s.
Collective self-efficacy (%)	77.19	11.20	77.24	13.24	77.37	11.58	n.s.	n.s.	n.s.
Enjoyment (scale 1–10)	8.41	2.03	8.71	1.88	8.60	1.38	n.s.	n.s.	n.s.
Satisfaction (scale 1–10)	6.79	1.73	7.11	2.50	7.00	1.73	n.s.	n.s.	n.s.

n.s., no significant; ES (RBC), effect size (Rank Biserial Correlation); TC-T1, Control Tournament vs. Tournament 1; TC-T2, Control Tournament vs. Tournament 1; T1-T2, Tournament 1 vs. Tournament 2.

the serve, which improves the ability to build the side-out (García-de-Alcaraz et al., 2017; Echeverria et al., 2019). This impacts game dynamics because it increases the continuity of the game (i.e., times that the ball passes over the net). The changes observed in experimental tournament 1 show the opposite tendency. The efficacy of serves increased and the efficacy of side-out phases decreased. The game had a faster pace than with the standard rules but lowering the net reduced receivers' possibilities to send the ball to the setter. This resulted in reduced side-out efficacy and increased quality and efficacy of the defense. The imbalance between serve and reception occurred despite the jump serves not being allowed, and serves were limited to two serves per player to avoid more skillful players increasing the serve-reception balance.

In Experimental Tournament 2, in which there were a reduction in the net height and court size as well as a serve limitation, the game dynamics were different. There was a reduction in serve efficacy, although the quality of its execution increased. The serve speed was lower, probably due to the reduction of the court size. This involved increased quality and efficacy of the reception and increased efficacy of the side-out. The number of blocks and defenses increased. Players adopted better defense positions before the opponent's attack was executed, although the defense quality and efficacy decreased. There was greater continuity in the game (i.e., number of rallies per play). The increased continuity and the way the offense was built increased the number of jumps, number of hits taken by the players, and

players' heart rate. There was a reduction in the time that players had to realize the reception, attack, and block due to the reduction in the distance of the court (court depth and width). The changes in Experimental Tournament 2 involved more balance between serve and reception which increased the efficacy of the side-out. The reduction in the court size meant that the distance between the setter and the attack destinations was smaller which allowed setters to increase the precision of their actions due to less force requirements. The change in the net height did not improve the attacker's efficacy, likely because the reduction of the net height was counter-balanced by the court size change (reduction of blockers' displacement, percentage of net zone covered by blockers, and percentage of court zone covered by defenders). However, there were more attacks and increased side-out efficacy during youth female volleyball matches. This net height reduction also involved more attacks being contacted by the blockers and defenders. The efficacy of the defense actions decreased, but, overall, there was an increase in the continuity of the game. The changes in the net height did not involve changes in the g-force in take-off and the landing of the attack. The limitations of the realization of jumps in the serve did not reduce the jumps done by players. These rule changes created game dynamics that were more similar to the progression found through the different developmental stages (García-de-Alcaraz et al., 2017; Echeverria et al., 2019). Side-out actions were done in situations that allowed players to have more successful experiences and happened with more frequency. Scaling the court size allowed players in this age group to better intercept the ball trajectories and interact with the ball. This increased the quality of the side-out, continuity, and participation in the game. The offense's success was achieved by having to overcome the block and defense that contacted the ball with more frequency. The reduction of the net height and court space involved players having to find different strategies to achieve points (e.g., increase attack speed, play against the block, etc.). The reason for the changes in Experimental Tournament 2 were the result of the combined impact of the limitations on the serve that were implemented (jump serve was not allowed and limit of two serves per player) and the changes in the net height and court size. Previous studies showed that a reduction of the court size increases the efficacy of the actions, except for the serve (Ronglan and Grydeland, 2006; Rocha et al., 2020a,b; Rodrigues et al., 2022). At the psychological level, none of the experimental tournaments involved changes regarding players' individual or collective self-efficacy, perceived enjoyment, or perceived satisfaction with regard to the Control Tournament. These findings could be due to the fact that this study assessed the immediate effect of the changes in the athletes' behaviors in a tournament. More studies are required to confirm this hypothesis.

The result of the current study must be interpreted with caution. The study only analyzed the immediate effect of the experimental rules in a specific group of players (three female regional teams) during two tournaments. Players did not practice using the experimental rules more than one day before the tournaments. This study does not allow us to establish the short-, medium-, or long-term impacts. This would require a research design that evaluates the impact of training and playing with these rules. More studies are needed with players of different levels (e.g., national and international levels) and sex. However, the results show that for this sample, scaling volleyball to players in U-14 may involve more players participation, quality of the execution, efficacy, and continuity. It is important to emphasize that this continuity did not just involve the ball passing over the net. To contribute to the better development of players, the game should involve and allow them to do successful varied actions. For that reason, it is important to study the interaction of the various rule changes and consider their combined impact. More studies are needed to establish which progressive evolution of rules is more appropriate for the different stages of development of youth volleyball players. These studies should analyze the effect of the different rule formats in each age group and their progression through the different stages of players development.

Conclusion

The experimental rules that were tested had different impacts on the game dynamics and players' actions. Scaling the net and adapting the serve rules (Experimental Tournament 1) altered the balance between serve and reception toward the serve, which resulted in an increase in the efficacy of serves and a decrease in the efficacy of side-out phases. This imbalance reduced the attack and blocks as well as the efficacy of these actions. Scaling the net and court and adapting the serve rules (Experimental Tournament 2) altered the balance between serves and reception toward the reception which increased the efficacy of side-out phases. These changes involved an increase in reception efficacy, the occurrence of attacks and blocks, game continuity, and players' effort. For the U-12 teams that were studied, this combination of competition rules resulted in game dynamics that were more similar to those observed in later stages of player development (i.e., García-de-Alcaraz et al., 2017; Echeverria et al., 2019). None of the experimental conditions involved changes regarding self-efficacy, perceived enjoyment, or perceived satisfaction with regard to the Control Tournament.

The competition rules during developmental stages could have a critical role in the player's development. Therefore, future studies are necessary to establish the proper rules for each age group to facilitate appropriate player development. The development process should be analyzed as a whole considering the evolution of the competition rules in each age group, their synchronization, progression, and their relationship from a holistic perspective. In the past, due to most of the studies being done in physical education, the manipulation of constraints focused on achieving continuity (i.e., three contacts per team). Future research must focus on the quality of the movement done by players to acquire and practice proper ways of skill execution (mechanical performance and avoiding injuries). This should be the basis to ensure (a) the precision of the actions (sending the ball to the target) that will allow for continuity of the game and allow other players to carry out proper executions and (b) the speed and power of the players' actions that allow them to apply their physical capacities and do not limit future improvements. Developmental stages are the critical period to develop the technique and speed integrated into the game actions and context (adapted from Balyi and Hamilton, 2004; Lloyd and Oliver, 2012; Pichardo et al., 2018).

The intended practical application of this study is increased knowledge about the combined effect of the manipulation of the different sports constraints on volleyball game dynamics and the need to study this impact from several dimensions (technical, tactical, physical, psychological, etc.). The impact of scaling the net and court alters the balance between serve and reception, impacting the occurrence, quality, and efficacy of the posterior actions, as well as the game continuity and physical efforts. In this research, the progression of the game dynamics observed in older age groups was used as a reference. For that reason, the manipulation of net height and court size was completed with serve limitation rules to promote more balanced game dynamics with more quality, efficacy, continuity, and variability. Future experimental studies with an intervention training period should verify whether this proposed rule modification achieves that or not.

Data availability statement

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

Ethics statement

The studies involving humans were approved by University Ethics Committee of University of Murcia (ID 1944/2018). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

JP: Conceptualization, Data curation, Investigation, Methodology, Validation, Writing—original draft. AU: Conceptualization, Supervision, Writing—review & editing. MM: Conceptualization, Supervision, Writing—review & editing. EO-T: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Writing—original draft, Writing—review & editing.

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Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1341297/full#supplementary-material

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Analyzing the impact of team-building interventions on team cohesion in sports teams: a meta-analysis study

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Introduction: Participation in team sports requires collaboration among multiple individuals over an extended period. Success in the game relies on more than just individual excellence; it necessitates effective teamwork. Team-building interventions have been shown to enhance team functioning, particularly in fostering cohesion among sports teams. This study aims to identify crucial factors in team-building interventions that contribute to improved team cohesion in sports teams.

Methods: A comprehensive meta-analysis of 15 articles was conducted to identify the crucial factors in team-building interventions that contribute to improved team cohesion in sports teams. The analysis focused on the age of participants, level of performance, and duration of interventions.

Results: The results of the analysis revealed that the positive impact of team-building was found to be most pronounced when the participants were between 15 and 20 years old, performed at collegiate teams, and engaged in interventions lasting more than 2 weeks. Among the four types of cohesion in sports teams, individual attraction to the group task (ATG-T) emerged as the aspect most influenced by team-building interventions.

Discussion: These findings provide valuable insights into the factors influencing the success of team-building interventions in enhancing team cohesion within sports teams.

KEYWORDS

group cohesion, group-based intervention, interactive sports, meta-analysis, teambuilding

1 Introduction

Psychological interventions in sports have proven effective in enhancing athletes' skill development, team cohesion, and team performance. Among these interventions, team-building has emerged as a prominent strategy for promoting effective collaboration among team members, thereby strengthening cohesion and team performance in sports teams. This approach has been employed to optimize the functionality of sports teams, resulting in improved team performance.

This study aims to explore the impact of team-building interventions on cohesion within sports teams. While numerous investigations have reported favorable effects of team-building on team cohesion (Cogan and Petrie, 1995; Prapavessis et al., 1996; Stevens and Bloom, 2003; Senécal et al., 2008; Kim and Kim, 2012; Durdubas and Koruc, 2023; Tassi et al., 2023), it remains challenging to assert that team-building interventions yield effective results. Some studies, such as those by Bloom and Stevens (2002), Kilty (2000), Kwon (2022), Prapavessis et al. (1996), and Rainey and Schweickert (1988), did not report positive developments in group cohesion.

Moreover, improvements in cohesion achieved through team-building interventions were sometimes transient, with studies indicating that cohesion levels were not sustained throughout the season (Cogan and Petrie, 1995; Stevens and Bloom, 2003). Drawing definitive findings about the effectiveness of team-building in sports is complicated by the diversity of methods and designs employed in these interventions, which yield unexpected results and necessitate an integrated examination of previous studies.

In the meta-analysis conducted by Carron et al. (2002), the impact of team-building on four subgroups of cohesion – GI-T (group integration–task), GI-S (group integration–social), ATG-T (individual attractions to the group-task), and ATG-S (individual attractions to the group-social) – was examined, with reported effect sizes of 0.471, 0.349, 0.676, and 0.463. Martin et al. (2009) conducted a meta-analysis on team-building interventions within sports teams, reporting an effect size of 0.427. Their analysis revealed that team-building interventions had the most substantial impact on cognitions ($g = 0.799$), with goal setting as the exclusive method coming in second ($g = 0.714$). The effect sizes of task and social cohesion were 0.263 and 0.214.

While team-building is known to have a positive effect on team cohesion, in actual application, its implementation time is limited. Therefore, to ensure that the cohesion effect is evident in sports teams, understanding the factors that should be considered in team-building interventions is crucial. This study seeks to determine which moderator variables such as gender, age, athletes' level, group size, and intervention duration, enhance the effect and which factors do not need to be considered.

2 Methodology

This methodology conforms to the relevant guidelines of the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) Statement and ensures that the necessary scientific information is provided in the field (Page et al., 2021).

2.1 Study selection and inclusion criteria

For this meta-analysis, literature selection focused on research studies examining the effectiveness of team-building interventions in interactive sport teams. The selection process followed rigorous and systematic procedures, incorporating keyword searches in computerized databases and employing a snowball sampling approach.

The computer-based search covered various databases, including PsychINFO, PsycARTICLES, SPORT Discus, and Google Scholar. This comprehensive search strategy involved using a range of keywords, such as "team-building in sport," "team-building intervention in sport," "team-building and cohesion," and various combinations.

Two independent reviewers extracted the following data from each article: study design, total number of participants, gender, age, intervention duration, and athletes' skill level. The accuracy of the extracted or calculated data was verified by comparing the data collection forms of the two investigators.

2.2 Dependent variables: cohesion

Team-building in sports teams can yield various outcomes, including enhanced cohesion. Carron and Spink (1993) developed a conceptual framework for team-building interventions in sports teams, designating group cohesiveness as the primary result of this process. Within this framework, four subgroups of cohesion, specifically GI-T, GI-S, ATG-T, and ATG-S, serve as dependent variables when assessing the impact of team-building interventions (Eys and Kim, 2017).

2.3 Moderating factors

2.3.1 Gender

Within the studies under review, two distinct demographic cohorts were examined. Specifically, 5 studies with 38 cases focused on male participants, while 10 studies with 14 cases centered around female participants.

2.3.2 Age of participants

The participants' ages were divided into three groups: under the age of 15, 15–20 years old, and over 20. Specifically, two studies with eight cases focused on participants under 15, while nine studies with 29 cases targeted the 15–20 age group, and four studies with 15 cases focused on participants over the age of 20.

2.3.3 Sample size

The sample size was categorized into three groups: under 20 participants, 20–30 participants, and over 30 participants. More specifically, five studies with 17 cases were centered on under 20 participants, while another five studies with 18 cases were aimed at the 20–30 participants group. Additionally, five studies with 17 cases were focused on participants comprising over 30 participants.

2.3.4 Skill level

The analysis covered a range of team proficiency levels. High school and collegiate teams were each represented in five studies with 16 effect sizes, whereas professional club teams were featured in five studies with 20 effect sizes.

2.3.5 Length of intervention

This study also investigated the duration of a team-building intervention as a potential moderator for their effectiveness. The intervention durations were classified into three groups: less than 2 weeks, 2 to 20 weeks, and 20 weeks or more. There were 8 studies with 32 cases that fell within the 2 to 20 weeks category, while 6 studies with 18 cases had intervention lasting over 20 weeks. Additionally, one study with two cases had an intervention duration of less than 2 weeks.

2.4 Coding methodology

Following established norms for meta-analytic research, we meticulously designed our coding procedure to thoughtfully capture and quantify crucial study characteristics and outcomes. Our comprehensive coding approach involved systematically extracting 11 essential pieces of information from each study. This included details

such as authorship, year of publication, study setting, study design type, sport type, duration of intervention, athletes' skill level, gender of participants, number of participants in experimental and control groups, means and standard deviations of intervention effectiveness at pretest and posttest, as well as effect size or measures of effectiveness.

2.5 Effect size calculations

The computation of effect sizes was conducted using R-4.3.2 for Windows.[1] This program provides various options for calculating effect sizes, and we chose Hedges g (Hedges and Olkin, 2014), an effect size adjusted to consider differences in sample size and sample variance. In interpreting the magnitude of effect sizes, we followed Cohen's (1988) guidelines. Specifically, a Hedges g of 0.80 was considered a large effect size, 0.50 signified a medium effect size, and 0.20 indicated a small effect size.

3 Results

3.1 Study selection

Following a database search, a total of 1,928 documents were initially identified, with 35 documents found through snowballing methods. After removing duplicates, 1,752 articles remained. Subsequently, 525 articles were excluded based on title screening. Application of the inclusion criteria led to the exclusion of an additional 664 articles. This left us with 121 articles that underwent full-text screening, focusing on articles potentially relevant to the impact of team-building interventions on cohesion in sports teams. To ensure methodological rigor, studies lacking the necessary statistical information for calculating effect sizes were excluded from the meta-analysis. Following these criteria, a total of 15 studies, comprising 52 cases, were considered eligible for inclusion in the meta-analysis (refer to Figure 1 for details).

3.2 Assessment of risk of bias

To assess the risk of bias in the included articles, we used the Cochrane Risk of Bias Tool (Higgins and Altman, 2008). This tool assesses each article based on a checklist comprising five items: randomization process, deviation from the intended intervention, missing outcome data, measurement of the outcome, and selection of the reported result. We then categorized each article's overall bias risk as low risk (indicating low risk across all items), some concerns, and high risk (indicating high risk of bias in at least one domain). Low risk indicates better methodological quality, while high risk suggests a high risk of bias.

Figure 2 provides a visual representation of risk of bias evaluations for each domain of the Cochrane Risk of Bias tool. Out of all included articles, 1 article (6.7%) had a low overall risk of bias, while 14 articles (93.3%) exhibited a high overall risk of bias. However, except for the randomization process domain, the other four checklist items showed low risk across all 15 articles.

The high prevalence of 'high' risk is attributed to the inherent challenges in randomly selecting teams, particularly in studies involving interactive sports teams. This difficulty arises from the complexities associated with randomly assigning teams in research focused on sports team dynamics.

3.3 Overall analysis

3.3.1 Overall effect size

The meta-analysis results, drawn from 52 individual cases extracted from 15 papers, are presented in Table 1. The table covers both the overall analysis and outcomes related to five moderating variables influencing cohesion. Additionally, Figure 3 illustrates a forest plot depicting effect sizes for the 52 individual cases. The overall analysis of these cases showed a significant moderate effect size (ES = 0.65, 95% CI = [0.40; 0.91]) of team-building intervention on cohesion. Additionally, the I^2 heterogeneity statistic indicated a significant level of heterogeneity at 96.9%.

3.3.2 Publication bias

To assess the potential presence of publication bias in our meta-analysis of team-building intervention on cohesion, we utilized a funnel plot for visual examination, as illustrated in Figure 4. In an ideal scenario without publication bias, data points (depicted as solid circles) from individual case studies would exhibit a symmetrical distribution. Any deviation from this symmetry suggests the potential presence of publication bias. As seen in Figure 4, the distribution of effect sizes is slightly left–skewed.

Applying the trim-and-fill method by Duval and Tweedie (2000) reveals that 15 missing studies on the right side are required to achieve symmetry in the funnel plot. The required 15 additional cases are shown on the right as hollow circles in Figure 4.

We also assessed publication bias using Rosenthal's (1979) fail-safe N (N_{fs}) concept. When N_{fs} exceeds 5k + 10, where k represents the number of included case studies, it is unlikely to substantially impact the average effect size. In our specific study, with k equal to 52, the meta-analysis results remain stable as long as the N_{fs} exceeds 270. Our N_{fs} value is 2,570, well above the 270 threshold, emphasizing the robustness of the meta-analysis. In simpler terms, even if more than 2,570 studies with zero effect size were introduced, the overall results would remain largely unaltered.

According to the trim-and-fill method by Duval and Tweedie (2000), an adjusted effect size of 1.00 (95% CI = [0.75; 1.25]), larger than the calculated effect size of 0.65, is presented.

3.4 Type of cohesion measure

Table 1 presents 52 effect sizes calculated for four cohesion types (GI-T, GI-S, ATG-T, and ATG-S). Notably, task cohesion exhibited a larger effect size than social cohesion. ATG-T showed a significant large effect size (ES = 1.06, 95% CI = [0.17; 1.95]). The other three cohesion types, GI-T (ES = 0.56, 95% CI = [0.23; 0.89]), ATG-S (ES = 0.56, 95% CI = [0.22; 0.91]), and GI-S (ES = 0.52, 95% CI = [0.01; 1.02]), showed a moderate effect size.

1 r-project.org

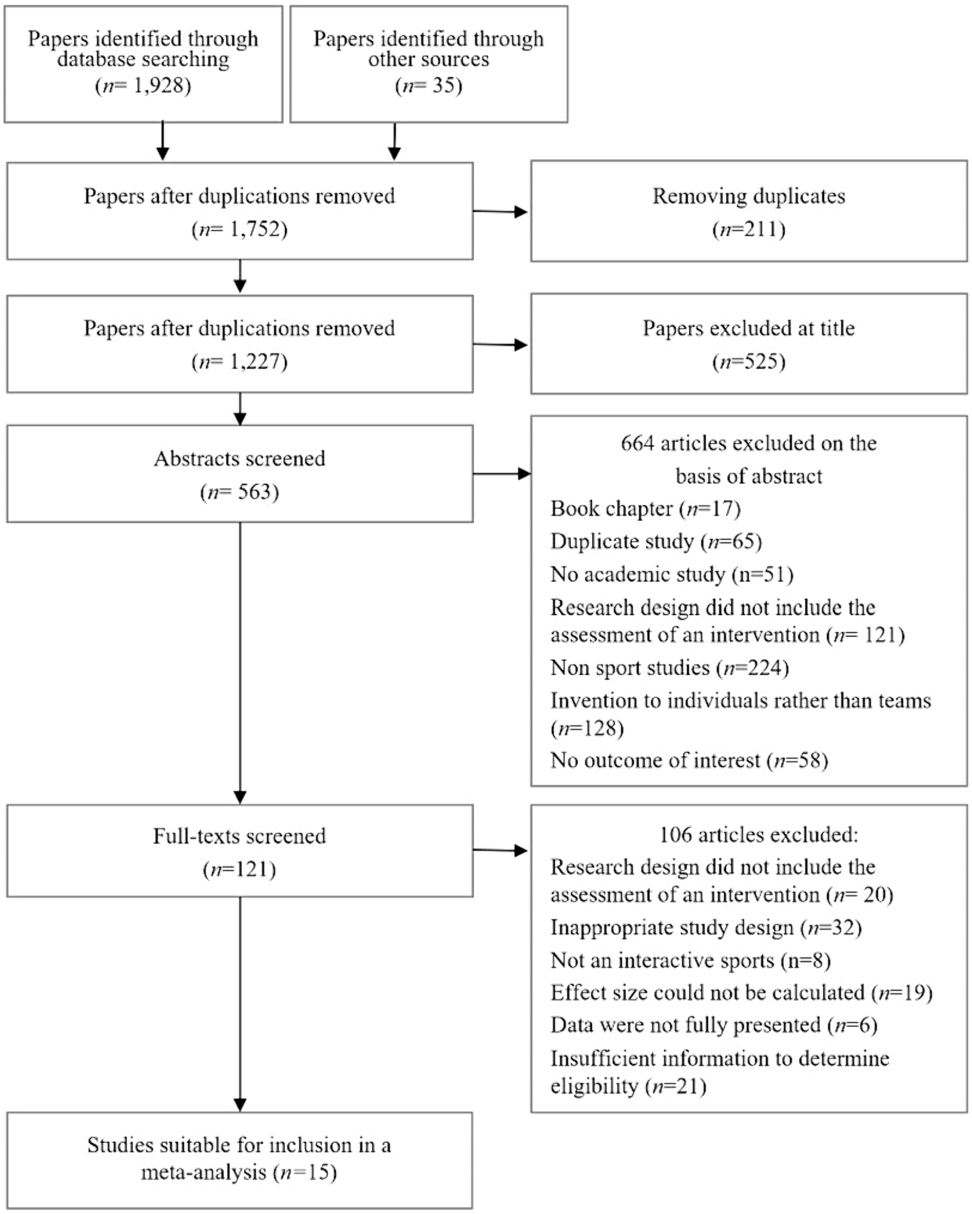

FIGURE 1
Flowchart of the systematic review process according to the PRISMA protocol declarations.

According to meta-ANOVA, the differences between the four cohesion types were not statistically significant ($F(3, 48) = 1.312$, $p > 0.05$).

3.5 Moderator variables

This study examined the effectiveness of team-building concerning five different moderators. These moderators encompassed the effectiveness of team-building on cohesion across gender, age, sample size, intervention duration, and athletes' skill level. Notably, the only significant moderator identified was athletes' skill level. No statistically significant differences were observed within the other four moderators (refer to Table 2 for details).

3.5.1 Gender

As indicated in Table 2, there is a slightly larger effect size for male athlete teams (ES = 0.66, 95% CI = [0.32; 1.00]) compared to female athlete teams (ES = 0.63, 95% CI = [0.43; 0.84]). However, the difference is not statistically significant ($p > 0.05$).

3.5.2 Age

We categorized the ages of the participants into three groups. In the 15–20 years old category, we observed a significant large effect size (ES = 0.88, 95% CI = [0.60; 1.15]), while those under the age of 15 showed a significant moderate effect size (ES = 0.48, 95% CI = [0.17; 0.78]). However, the effect size (ES = 0.25, 95% CI = [−0.45; 0.96]) for those over the age of 20 was not statistically significant. The meta-ANOVA analysis indicated that the difference between these three

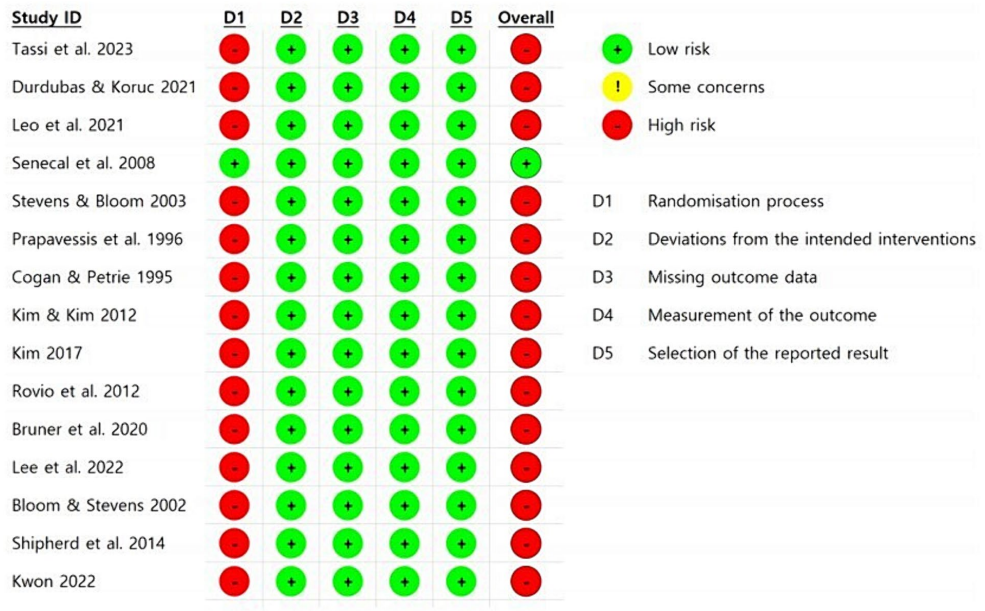

FIGURE 2
Assessment of risk of bias in the included studies.

TABLE 1 Effect sizes of dependent variables.

Dependent variable	*n*	*Effect size*	I^2 (%)	95% CI	
				LL	UL
Overall	52	0.65	96.9	0.39	0.91
GI-T	14	0.56	96.8	0.23	0.89
GI-S	15	0.52	96.7	0.01	1.02
ATG-T	11	1.06	97.9	0.17	1.95
ATG-S	12	0.56	96.6	0.22	0.91

categories was not statistically significant ($p > 0.05$). Consequently, age was not identified as a significant moderator in this study.

3.5.3 Sample size

The sample size was divided into three groups. In the category with 20–30 participants, we observed a significant large effect size (ES = 0.85, 95% CI = [0.49; 1.21]). Additionally, the category with under 20 participants showed a significant moderate effect size (ES = 0.64, 95% CI = [0.49; 1.21]). However, the effect size (ES = 0.50, 95% CI = [−0.03; 1.31]) for those over 30 participants was not statistically significant. The meta-ANOVA analysis indicated that the difference between these three categories was not statistically significant ($p > 0.05$). Consequently, the sample size was not identified as a significant moderator in this study.

3.5.4 Length of intervention

The team-building interventions in our study varied in duration, ranging from 1 day to the entire sports season. As shown in Table 2, a significant moderate effect size (ES = 0.69, 95% CI = [0.31; 1.06]) was observed for interventions lasting between 2 and 20 weeks. Additionally, a significant moderate effect size was evident for interventions extending for 20 weeks or longer (ES = 0.62, 95% CI = [0.43; 0.82]). However, the effect size (ES = 0.31, 95% CI = [−0.97; 1.60]) for intervention durations less than 2 weeks was not statistically significant. The meta-ANOVA analysis indicated that the difference between these three categories was not statistically significant ($p > 0.05$). Consequently, the length of intervention was not identified as a significant moderator in this study.

3.5.5 Skill level of the athletes

As outlined in Table 2, we observed a significant large effect size (ES = 1.13, 95% CI = [0.53; 1.72]) in the category of collegiate teams, while we identified a significant moderate effect size (ES = 0.77, 95% CI = [0.59; 0.95]) in the category of high school teams. However, the effect size (ES = 0.40, 95% CI = [−0.02; 0.83]) was not statistically significant for professional teams.

According to the meta ANOVA and post-hoc test results, significant differences ($p < 0.05$) in the effectiveness of team-building on cohesion were found between collegiate teams and professional teams. Consequently, athletes' skill level can act as a moderator in the effectiveness of team-building intervention on cohesion.

3.6 Meta-regression analysis

We conducted meta-regression analyses to explore the association between three independent variables (age, sample size, and duration in weeks) and the effect size. The results of meta-regression analysis showed that the effect size tend to decrease with mean age, although this association did not reach statistical significance ($p > 0.05$) (refer to Figure 5 and Table 3). Furthermore, the relationships between sample size and effect sizes, as well as the relationship between duration in weeks and effect sizes, did not show statistical significance ($p > 0.05$) (refer to Table 3).

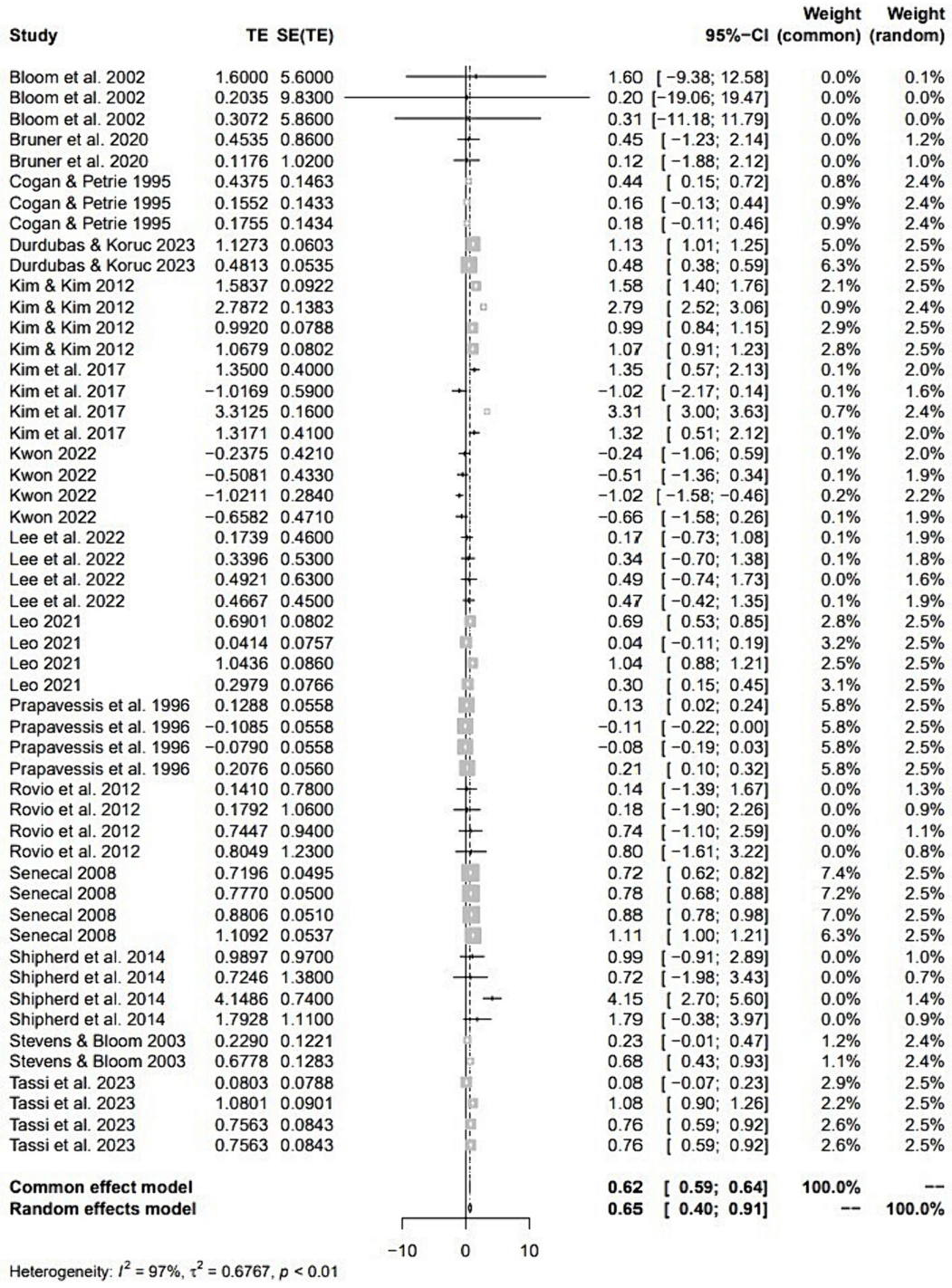

FIGURE 3
Forest plot of meta-analysis for team building intervention on cohesion in sports teams. The individual effect sizes are identified as Hedges g with lower and upper limits of 95% CIs.

4 Discussion

The main goal of this meta-analysis is to assess the impact of team-building interventions on cohesion, a critical element in sports teams that plays a pivotal role in task execution and fostering social interactions (Carron and Spink, 1993; Carron et al., 1997). If team-building interventions focused on fostering cohesion can establish a sense of unity among team members, they have the potential to serve as catalysts for enhancing overall team performance.

Our study's key finding is that team-building activities indeed improve cohesion in sports teams. Among various measures of cohesion, we found that team-building interventions were most successful in enhancing ATG-T, followed by GI-T, GI-S, and

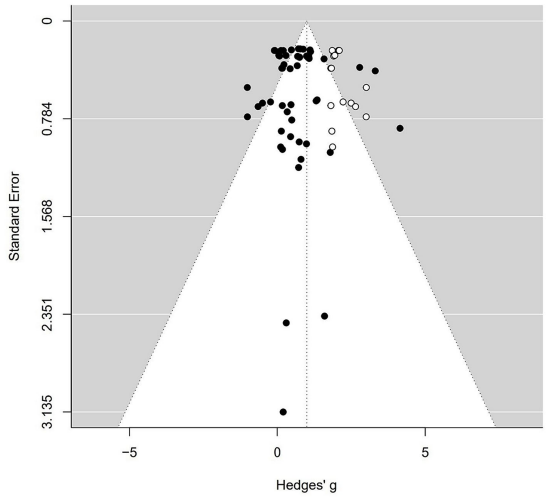

FIGURE 4
Funnel plot of standard error by Hedges g.

ATG-S. Some team-building activities focus on social aspects, like team camping trips (Cogan and Petrie, 1995), ropes and challenge courses (e.g., Meyer, 2000), and informal social gatherings (e.g., Yukelson, 1997). These activities are likely to enhance social cohesion within the team. On the other hand, other team-building activities concentrated on team goals and tasks, such as team goal-setting (e.g., Senécal et al., 2008; Kim et al., 2017; Durdubas and Koruc, 2023), tasks relevant to team performance (e.g., Leo et al., 2021), clarifying roles (e.g., Tassi et al., 2023), and adhering to team norms (e.g., Prapavessis et al., 1996). These activities are expected to primarily improve task cohesion within the team. Notably, our analysis revealed a stronger impact of team-building activities on task cohesion compared to social cohesion due to the predominant focus on tasks and objectives rather than social interactions in the studies examined.

Another aim of our study is to explore how various moderator variables affect the improvement of cohesion through team-building intervention. Several findings are associated with the influence of moderators. To begin with, we explored gender as a potential moderator. The findings indicate that team-building interventions are equally effective for teams composed solely of females as well as those with only males. In our meta-analysis, using gender served as a potential moderator, the results of the meta *t*-test showed no significant difference ($p > 0.05$) in the effectiveness of team-building interventions applied to both men's and women's teams. This aligns with the results reported by Martin et al. (2009).

In this study, the second potential modulator under scrutiny was the age of participants. We categorized subjects of individual study into three age groups, and then the effect size was calculated with age as a moderate variable. We found that the age category of 15–20 exhibited a large effect size, while the category under 15 years old showed a significant moderate effect size. However, there was no significant effect size observed for the category of those aged over 20 years. Consequently, we can conclude that team-building is most effective for sports teams with members between 15 and 20 years old, while it does not show effectiveness for sports teams with members aged over 20.

In our analysis, the third potential modulator we explored was sample size. We classified the sample size of each study into three groups, and then the effect size was calculated with sample size as a moderate variable. In the group with 20–30 participants, a significant large effect size was observed, while the category with under 20 participants showed a significant moderate effect size. However, there was no significant effect size observed for the category of those with over 30 participants. As a result, we can conclude that team-building is most effective for sports teams ranging from 20 to 30 members, while it does not show effectiveness for sports groups with over 30 members.

In our analysis, the fourth potential modulator we explored was athletes' skill level, which turned out to be the only significant moderator in this study. Team-building interventions were most effective for collegiate teams, followed by high school teams, while the effectiveness in professional teams did not reach statistical significance ($p > 0.05$). This discrepancy may be explained by a potential ceiling effect, given that professional athletes typically possess a strong understanding of cohesion. Consequently, while professional teams do benefit from team-building interventions, the extent of improvement may be comparatively modest due to their already robust cohesion and training. The meta-ANOVA indicated that the differences between the three groups were statistically significant ($p < 0.05$), and the post-hoc test revealed that the effect size of the collegiate team was larger than that of the professional club team. Thus, it can be concluded that team-building is most effective for collegiate sports teams, while it does not show effectiveness for professional club teams.

Moving on to the fifth potential modulator, we explored intervention duration. The articles in this meta-analysis encompassed team-building interventions with durations ranging from a single day to an entire sports season. Notably, interventions lasting less than 2 weeks did not yield noticeable improvements in cohesion and were not statistically significant, aligning with the findings of Martin et al. (2009). Conversely, Shipherd et al. (2014) conducted a single-day team-building intervention with a collegiate rugby team and observed a significant increase in team cohesion. These disparities in intervention duration underscore the need for meta-analytic investigations to gain a comprehensive understanding of the optimal duration required for team-building interventions to enhance cohesion in future studies.

Although numerous studies have demonstrated the positive effects of team-building interventions on cohesion, there are instances, as seen in some studies (Prapavessis et al., 1996; Kwon, 2022), where significant improvements were not observed. The intervention period might have impacted why there wasn't a significant change in group cohesion after the team-building program was implemented. Kwon (2022) and Prapavessis et al. (1996) conducted a team-building intervention over 8 weeks but did not find a clear improvement in group cohesion. This suggests that the intervention duration might have been too short to see significant differences in these studies. Group cohesion improves gradually through changing members' perceptions and resolving conflicts that arise during interactions. Therefore, steady progress over a long enough time is important. However, conducting long-term team-building interventions can be challenging due to various environmental factors.

TABLE 2 Moderator effects.

Potential moderator	*F*-test	*p*	Effect size	*n*	95% CI
Average effect size from individual studies			0.65	52	[0.42; 0.89]
Gender	$F(1, 50) = -0.169$	ns			
Female only			0.63	14	[0.43; 0.84]
Male only			0.66	38	[0.32; 1.00]
Mean age	$F(2, 49) = 2.306$	ns			
<15 years			0.48	8	[0.17; 0.78]
15–20 years			0.88	29	[0.60; 1.15]
>20 years			0.25	15	[−0.45; 0.96]
Sample size	$F(2, 49) = 0.304$	ns			
<20			0.64	17	[0.49; 1.21]
20–30			0.85	18	[0.49; 1.21]
>30			0.50	17	[−0.03; 1.31]
Length of intervention	$F(2, 49) = 0.264$	ns			
Less than 2 weeks			0.31	2	[−0.97; 1.60]
2 to 20 weeks			0.69	32	[0.31; 1.06]
20 weeks and above			0.62	18	[0.43; 0.82]
Skill level	$F(2, 49) = 3.315$	<0.05			
High School			0.77	16	[0.59; 0.95]
Intercollegiate			1.13	16	[0.53; 1.72]
Professional club			0.40	20	[−0.02; 0.83]

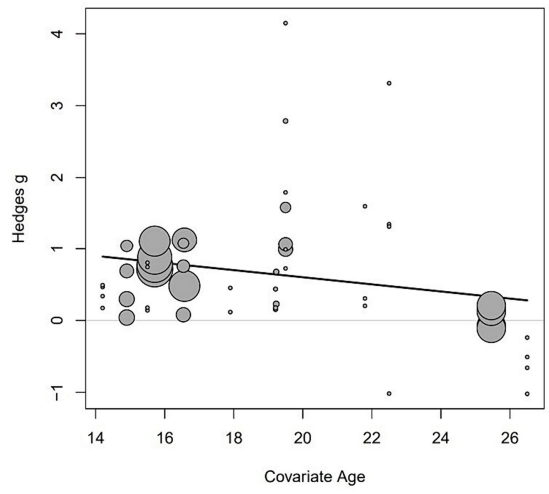

FIGURE 5
Meta-regression analysis of the relationship between Hedges' g and the mean age of participants.

5 Conclusion

In conclusion, this study provides several key insights into the impact of team-building intervention on cohesion within sports teams. Firstly, team-building activities predominantly enhance task cohesion rather than social cohesion within sports teams. Different approaches to team-building, focusing on either social interactions or team goals and tasks, result in corresponding improvements in cohesion. Thus, social cohesion benefits from team-building activities emphasizing social interaction, while task cohesion improves when activities concentrate on team objectives.

Secondly, team-building interventions are most effective for individuals aged 15–20 and within collegiate sports teams. Conversely, the expected positive effects may not be noticeable when subjects are over 20 years old and belong to professional league teams.

Thirdly, interventions lasting longer than 2 weeks are crucial for enhancing team cohesion. Conversely, the expected positive effects may not be noticeable if the intervention period is less than 2 weeks. Based on our findings, an intervention period of at least 2 weeks is necessary to see the effects of a team-building intervention on group cohesion in sports teams. However, it is not necessarily the case that a longer intervention period will result in a greater intervention effect. Additionally, the time delay of the intervention was not investigated in this study. Therefore, the association between the team-building intervention period and group cohesion remains unclear. Further research is needed to determine the optimal intervention period that significantly affects group cohesion. It is also important to consider the time delay of intervention. Furthermore, there is possibility that a group cohesion may be influenced by multiple processes rather than just team-building alone. Therefore, claiming that team-building alone enhances group cohesion may not be reasonable. Therefore, decision-makers in sports teams should carefully consider the duration and realistic expectations of team-building interventions. In any case, to have an effective team-building intervention, it is necessary to implement the intervention for a long enough period. To address this, leaders should ensure interventions are implemented over a sufficient period to yield meaningful results.

TABLE 3 Univariate meta-regression analysis.

Moderator	β	SE	t	p
Mean age	−0.044	0.033	−1.339	0.187
Sample size	−0.004	0.010	−0.351	0.727
Duration (in weeks)	−0.012	0.022	−0.549	0.587

In summary, team-building interventions can significantly enhance cohesion within sports teams, particularly when tailored to specific team dynamics and implemented over a sufficient duration.

Nevertheless, it's important to note the limitations of this meta-analysis. First and foremost, the study focused exclusively on interactive sports, suggesting the need for future research to explore and compare the effectiveness of team-building interventions in both interactive and coactive sports settings. Secondly, the review concentrated solely on immediate post-intervention effects, emphasizing the necessity for longitudinal studies to gain a more profound understanding of the lasting benefits of team-building interventions for sports teams over an extended period.

Data availability statement

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

Author contributions

SK: Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

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Position and ranking influence in padel: somatic anxiety and self-confidence increase in competition for left-side and higher-ranked players when compared to pressure training

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This study aimed to analyze the differences in the precompetitive anxiety and self-confidence according to the side of play, the ranking and the match outcome, under different competitive scenarios, in high level men's padel players from Finland who trained under pressure prior to the competition. 10 men's padel players (28.60 (4.17) years old) from the highest category participated in the research. The CSAI-2R (Competitive State Anxiety Inventory-2 Revised) and STAI-S (State–Trait Anxiety Inventory – State) questionnaires were used and descriptive and inferential analyzes were performed, including Mann–Whitney's *U* tests. The findings illuminate that, across the player spectrum, somatic anxiety and self-confidence levels are higher before competition compared to training matches. This trend holds true for left-side, higher-ranked and match winning players. Even lower-ranked players exhibit heightened self-confidence preceding competitions. These insights offer valuable considerations for players, coaches, and sports psychologists, fostering a deeper understanding of the intricate interplay between pressure training, competition, and the athlete's psychological landscape.

KEYWORDS

psychology, confidence, anxiety, competition, practice, padel, CSAI-2R, STAI-S

Introduction

The global surge of padel, a doubles racket sport, has attracted participants from over 60 nations affiliated with the International Padel Federation (2024). This growth has triggered a notable rise in scholarly research focused on psychophysiology (Conde-Ripoll et al., 2023; Díaz-García et al., 2023a; Bustamante-Sánchez et al., 2024), although technical-tactical performance remains a dominant area of study (Lupo et al., 2018; Escudero-Tena et al., 2021; Martín-Miguel et al., 2023; Conde-Ripoll et al., 2024; Ungureanu et al., 2024).

Participating in sports may involve rigorous physical exertion and significant psychological burdens, posing challenges for certain athletes to handle and potentially resulting in adverse outcomes (Balaguer et al., 2012). This phenomenon becomes more pronounced when high-level padel players are required to compete in two consecutive matches within a single day,

leading to a notable build-up of cognitive exhaustion which intensifies perceived mental fatigue (Díaz-García et al., 2023b). On its part, anxiety encompasses a negative emotional state characterized by nervousness, worry, and apprehension, typically accompanied by heightened physiological arousal (Weinberg and Gould, 2010). This state leads to an individual's diminished adaptability across physiological, behavioral, and cognitive realms, thereby obstructing athletic performance (Tamorri, 2004). Anxiety often escalates immediately before competition and subsides shortly afterward (Gould et al., 1984). Numerous studies have confirmed that heightened pre-competitive anxiety can hinder athletic performance (Burton, 1988).

To comprehend this anxious state, the multidimensional theory (Martens et al., 1990) suggests that subjective expressions of anxiety involve cognitive and somatic components, along with self-confidence. The somatic aspect encompasses the physiological and emotional facets of anxiety, originating directly from organismic activation (Martens et al., 1990). It encompasses a range of physical symptoms (elevated levels of physiological function activation) triggered automatically by the demands of competition (Dosil, 2004), often accompanied by nervousness and tension. Conversely, cognitive anxiety pertains to the mental dimension of anxiety, arising from negative expectations or low self-confidence levels in oneself and one's abilities (Martens et al., 1990). A third aspect, self-confidence, while not a direct measure of anxiety, can influence athletes' experience of cognitive anxiety. Self-confidence reflects an individual's belief in their capacity to manage their surroundings and themselves (Woodman and Hardy, 2001). Prior to Spanish competitions, high-level (first category) padel players exhibit higher levels of self-confidence and lower levels of somatic-anxiety when compared to players from third category (Castillo-Rodriguez et al., 2022).

Training should be tailored to prepare players for competition in the best possible way. A comparison between the demands of competition and training suggests that the former typically imposes higher physiological demands, coupled with psychological factors such as the allure of victory, competition prestige, and the challenge posed by rival athletes. Souza et al. (2019) observed elevated somatic anxiety, LH/HF ratio, and cortisol levels preceding competitions in contrast to training, what suggest an excitement of the autonomous nervous system on its sympathetic division. As relevant competitions approach, as exemplified in our study with training occurring 2 weeks prior to a key event, research suggests an increase in stress and anxiety levels among athletes (Loupos et al., 2008; Morales et al., 2014; Bustamante-Sánchez et al., 2024). In racket sports, contemporary methodologies advocate for competitive training scenarios mirroring match-play conditions to enhance decision-making proficiency in authentic settings (Mecheri et al., 2019; Navia et al., 2022). It is important to highlight that in racket sports like padel, where rapid decision-making is constant (Castillo-Rodríguez et al., 2014), effectively managing pressure situations directly influences performance (González-Díaz et al., 2012; Knight et al., 2016; Martínez-Gallego et al., 2022). Since mental strength plays a pivotal role in sports success (Crust and Keegan, 2010) and in upholding or boosting competitive performance (Gucciardi et al., 2015), players need to develop their mental skills (Mamassis and Doganis, 2004) as well as pressure should be present during training sessions (Low et al., 2021). Although replicating competition can be difficult, training under mild levels of pressure can still benefit future performance under higher levels of pressure (Oudejans and Pijpers, 2010). Pressure training is an intervention that applies pressure on athletes while they practice their sport with the aim of helping them improve their performance under pressure (Low et al., 2021). In other words, it attempts to increase pressure above the level that athletes feel in a typical training session. In this regard, Stoker et al. (2016) examined stressors that elite-level coaches, among a wide spectrum of sports like badminton and table tennis, used to intentionally create pressure during training sessions. The ensuring framework categorized stressors into demands and consequences. The former increased the difficulty to perform (for example, adding distractions to the environment or changing the rules of a drill), whereas the latter included rewards (e.g., the change to choose the next tournament abroad), forfeits (e.g., having to miss a training session), or judgment (e.g., being watched by the professional team's performance director). Subsequent research found that consequences increase pressure more than demands do (Stoker et al., 2017, 2019).

Despite the growing interest in padel, a notable gap exists in the scientific literature regarding the consideration of pressure training, the comparison of precompetitive anxiety levels between training and competition contexts, and between players based on their side of play. Our study aims to address this gap by investigating these aspects within the padel domain, providing valuable insights into the psychological dynamics of player performance. By examining the effects of pressure training and elucidating differences in anxiety levels between training and competition, and between right- and left-side players, we aim to offer a novel contribution to the field. These findings hold significant practical implications for players, coaches, and sports psychologists, as they can inform tailored strategies for optimizing player performance and well-being. Players may benefit from lifestyle modifications and adjustments to playing style, while coaches and psychologists can tailor training sessions and feedback to better support players in managing anxiety and enhancing self-confidence.

Therefore, the aim of the present investigation was to analyze the differences in the pre-competitive anxiety and self-confidence between training and competition in high-level men's padel players from Finland who trained under pressure, according to the side of play, the ranking, and the match outcome. The following hypotheses were put forward: (1) prior to competition, athletes will show higher levels of anxiety and lower levels of self-confidence than prior to training matches, (2) left-side players, as well as right-side players, will show higher levels of self-confidence and less anxiety before competition than prior to training matches, (3) both prior to training and competitive matches, left-side players will present lower levels of anxiety and higher levels of self-confidence when compared to right-side players, (4) higher ranked players will show similar levels of anxiety and self-confidence between competition and training matches while lower ranked players will show lower levels of self-confidence and higher levels of anxiety before competition than training matches, (5) match winning players will show similar levels of anxiety and self-confidence between competition and training matches while match losing players will show lower levels of self-confidence and higher levels of anxiety before competition than training matches.

Materials and methods

Sample and participants

A total of 10 men's high level padel players (28.60 (4.17) years old) from Finland voluntarily participated in the present study. All participants were ranked top 25 in Finland. None of the athletes had physical injuries, nor were they using any medication. In addition, none of the participants had any reason that prevented them from participating in the study. The sample consisted of 20 matches (training: 11, competition: 9). The training matches took place at Padel Tampere Linnakallio New during the 2 weeks prior to the 2023 Finnish national championship by pairs. The obtained points of this competition counted for the ranking of the Finnish Federation. The study was in accordance with the Helsinki Declaration (World Medical Association, 2013). Participants were treated ethically under the American Psychological Association code of ethics regarding consent, anonymity and responses. Previously, the current investigation had been approved by the Ethics Committee of the European University of Madrid with the code CIPI/22.303. So as to respect the principles of voluntariness and confidentiality, each player was required to sign an informed consent form that clearly explained the objectives of the research and their voluntary participation in it. To obtain permission to administer the questionnaires to the players before the competition, the researchers first contacted the Finnish Padel Federation and the championship organizer.

Instruments

Competitive anxiety

CSAI-2R was used to measure precompetitive anxiety and self-confidence of players (Cox et al., 2003) and STAI-S was used to measure their state anxiety (Spielberger et al., 1970). These questionnaires have been used in previous research in padel (Conde-Ripoll et al., 2023). In the analysis of the CSAI-2R instrument, Cronbach's alpha coefficients were obtained, showing reliability scores of 0.515 for cognitive anxiety, 0.808 for somatic anxiety, 0.758 for self-confidence, all but the former meeting acceptable standards (Nunnally and Bernstein, 1994; DeVellis, 2003; Vaske, 2008).

Procedure

The players were informed by the coach that they would undergo pressure training. Pressure training refers to an intervention designed to assist athletes in performing under pressure by deliberately exposing them to stressors during training sessions (Bell et al., 2013; Driskell et al., 2014; Stoker et al., 2016). In our study, players were recorded during the training matches while their technical-tactical performance was exhaustively evaluated by the head coach of the first-ever professional padel team in Finland. Players were informed about this process before the training match began.

The questionnaires were administered to the players between 30 and 45 min prior to the start of each match, following the same criteria to that used by Andrade-Fernández et al. (2007) and Conde-Ripoll et al. (2023). All questionnaires were completed in a quiet room with controlled temperature of 20°C. Participants completed the questionnaires in English, as it is the only language that both researchers and athletes are fluent in. Participants were not allowed to speak during the assessments.

Statistical analysis

A Kolgomorov-Smirnov test was used to test the normality of the distribution of the data and it indicated that it is non-parametric. Then, results were shown as median and interquartile range.

Next, inferential analyzes were conducted, including Mann–Whitney's U tests. Additionally, effect sizes (Cohen's d) were calculated and can be interpreted as small (0.20 to 0.49), moderate (0.50 to 0.79) and large ($d \geq 0.80$) (Cohen, 1988).

All data were analyzed using the statistical package SPSS for Macintosh v.25.0 (SPSS Inc., Chicago, IL, United States). A p value of less than 0.05 was considered to be statistically significant.

Results

Results are shown as mean and interquartile range.

Table 1 presents the level of precompetitive anxiety and self-confidence between players at training and at competition matches. Players significantly present higher levels of somatic anxiety ($p = 0.025$; $d = 0.602$) and self-confidence ($p = 0.002$; $d = 0.848$) in competition when compared to training matches.

Table 2 further examines the level of precompetitive anxiety and self-confidence between players at training and at competition matches as a function of the side of play. Left-side players significantly present higher levels of somatic anxiety ($p = 0.045$; $d = 0.708$) and self-confidence ($p = 0.002$; $d = 1.265$) in competition when compared to training matches.

Table 3 depicts the level of precompetitive anxiety and self-confidence between right- and left-side players at training and at competition matches. Before training matches, right-side players

TABLE 1 Precompetitive anxiety and self-confidence between players at training and at competition matches.

Variable	Training	Competition		
	Median (IQR)	Median (IQR)	*p*	*d*
CA	1.40 (0.40)	1.20 (0.40)	0.371	0.228
SA	1.43 (0.71)	1.71 (0.57)	0.025*	0.602
SC	3.10 (0.60)	3.40 (0.60)	0.002*	0.848
STA	7.00 (5.00)	6.00 (2.00)	0.900	0.032

CA, cognitive anxiety; SA, somatic anxiety; SC, self-confidence; STA, state anxiety; n, number; IQR, interquartile range; *p*, *p*-value; *$p < 0.05$; *d*, Cohen's d.

TABLE 2 Precompetitive anxiety and self-confidence between players at training and at competition matches according to the side of play.

Variable	Left-side player				Right-side player			
	Training	Competition			Training	Competition		
	Median (IQR)	Median (IQR)	*p*	*d*	Median (IQR)	Median (IQR)	*p*	*d*
CA	1.40 (0.40)	1.20 (0.10)	0.231	0.404	1.50 (0.70)	1.20 (0.40)	0.801	0.099
SA	1.14 (0.61)	1.57 (0.43)	0.045*	0.708	1.57 (0.57)	1.86 (0.14)	0.201	0.520
SC	3.20 (0.40)	3.40 (0.60)	0.002*	1.265	3.00 (0.70)	3.20 (0.80)	0.175	0.557
STA	5.00 (4.00)	6.00 (2.00)	0.413	0.281	9.50 (3.00)	7.00 (5.00)	0.167	0.569

CA, cognitive anxiety; SA, somatic anxiety; SC, self-confidence; STA, state anxiety; n, number; IQR, interquartile range; *p*, *p*-value; $*p < 0.05$; *d*, Cohen's d.

TABLE 3 Precompetitive anxiety and self-confidence between right- and left-side players at training and at competition matches.

Variable	Training				Competition			
	Left	Right			Left	Right		
	Median (IQR)	Median (IQR)	*p*	*d*	Median (IQR)	Median (IQR)	*p*	*d*
CA	1.40 (0.40)	1.50 (0.70)	0.619	0.168	1.20 (0.10)	1.20 (0.40)	0.525	0.285
SA	1.14 (0.61)	1.57 (0.57)	0.016*	0.873	1.57 (0.43)	1.86 (0.14)	0.091	0.754
SC	3.20 (0.40)	3.00 (0.70)	0.281	0.374	3.40 (0.60)	3.20 (0.80)	0.134	0.662
STA	5.00 (4.00)	9.50 (3.00)	< 0.001*	1.480	6.00 (2.00)	7.00 (5.00)	0.260	0.489

CA, cognitive anxiety; SA, somatic anxiety; SC, self-confidence; STA, state anxiety; n, number; IQR, interquartile range; *p*, *p*-value; $*p < 0.05$; *d*, Cohen's d.

TABLE 4 Precompetitive anxiety and self-confidence between players at training and at competition matches according to the ranking.

Variable	Higher-ranked				Lower-ranked			
	Training	Competition			Training	Competition		
	Median (IQR)	Median (IQR)	*p*	*d*	Median (IQR)	Median (IQR)	*p*	*d*
CA	1.30 (0.40)	1.20 (0.20)	0.397	0.281	1.40 (0.50)	1.20 (0.80)	0.806	0.097
SA	1.29 (0.61)	1.71 (0.50)	0.005*	1.075	1.50 (0.61)	1.71 (0.57)	0.582	0.219
SC	3.20 (0.30)	3.40 (0.80)	0.046*	0.717	3.00 (0.60)	3.40 (0.80)	0.019*	1.053
STA	6.50 (4.00)	6.00 (2.00)	0.767	0.101	8.00 (6.00)	7.00 (5.00)	0.927	0.036

CA, cognitive anxiety; SA, somatic anxiety; SC, self-confidence; STA, state anxiety; n, number; IQR, interquartile range; *p*, *p*-value; $*p < 0.05$; *d*, Cohen's d.

present significantly higher levels of somatic anxiety ($p = 0.016$; $d = 0.873$) and state anxiety ($p < 0.001$; $d = 1.480$) than left-side players.

Table 4 delves into the variation of the levels of precompetitive anxiety and self-confidence between players at training and at competition matches as a function of the ranking. Higher-ranked players present significantly higher levels of somatic anxiety ($p = 0.005$; $d = 1.075$) and self-confidence ($p = 0.046$; $d = 0.717$) at competition when compared to training matches. Lower-ranked players present significantly higher levels of self-confidence ($p = 0.019$; $d = 1.053$) at competition when compared to training matches.

Table 5 shows the level of precompetitive anxiety and self-confidence between players at training and at competition matches as a function of the match outcome. Winning players present significantly higher levels of somatic anxiety ($p = 0.026$; $d = 0.824$) and self-confidence ($p = 0.014$; $d = 0.922$) at competition when compared to training matches.

Discussion

The aim of the present study was to evaluate anxiety and self-confidence prior to training matches and sports competition in high level men's padel players from Finland. The initial hypothesis positing higher levels of anxiety and lower levels of self-confidence before competitive matches compared to training matches was only partially supported by the findings. Our findings revealed significant differences in self-confidence and somatic anxiety. Specifically, higher levels were reported prior to competition than before training matches. These observed differences may be attributed to several key factors. Firstly, the heightened excitement and importance associated with official matches might inspire top players to exhibit their utmost self-assurance. The challenges inherent in an official game may lead athletes to rely on their skills and positive beliefs, thereby boosting their self-confidence and somatic anxiety levels. Additionally, the structured and organized nature of competitive play, coupled with the presence of spectators and the pursuit of tangible outcomes, may

TABLE 5 Precompetitive anxiety and self-confidence between players at training and at competition matches according to the match outcome.

Variable	Winning players				Losing players			
	Training	Competition			Training	Competition		
	Median (IQR)	Median (IQR)	*p*	*d*	Median (IQR)	Median (IQR)	*p*	*d*
CA	1.20 (0.50)	1.20 (0.20)	0.638	0.158	1.40 (0.50)	1.20 (0.80)	0.865	0.065
SA	1.36 (0.61)	1.71 (0.57)	0.026*	0.824	1.43 (0.61)	1.79 (0.36)	0.169	0.554
SC	3.20 (0.40)	3.40 (0.60)	0.014*	0.922	3.00 (0.50)	3.20 (1.00)	0.101	0.666
STA	7.00 (4.00)	6.00 (1.00)	0.927	0.031	8.00 (6.00)	8.00 (9.00)	0.889	0.054

CA, cognitive anxiety; SA, somatic anxiety; SC, self-confidence; STA, state anxiety; n, number; IQR, interquartile range; *p*, *p*-value; $*p < 0.05$; *d*, Cohen's d.

foster a heightened sense of readiness and physiological arousal in players. In comparison to previous research, our findings align with certain patterns observed by Cervantes Blásquez et al. (2009) in swimmers, where similar differences in somatic anxiety were noted between training and competition. Likewise, Souza et al. (2019) found that somatic anxiety remained stable in canoe athletes, street runners and jiu-jitsu fighters a few days prior to the event but show a sudden rise and reach a peak at the onset of the competition. Interestingly, Mateo et al. (2012) also showed that somatic anxiety was lower 3 days before the first day of competition in BMX riders, although the opposite happened to self-confidence.

Another hypothesis was that left-side players, as well as right-side players, will show higher levels of anxiety and lower levels of self-confidence before competition than prior to training matches. This hypothesis was partially accepted. We observed that left-side players presented higher levels of somatic anxiety and self-confidence before competition than before training matches. However, it is crucial to note that no significant differences were found among right-side players in the same comparison, indicating unique psychological responses based on player positions. These results may be indicative of the distinctive responsibilities and pressures experienced by players during critical moments in a match. The higher involvement of the left-side player in the penultimate and last shots of the points (Ramón-Llín et al., 2022) aligns with the idea that their perceived role in shaping match outcomes could contribute to heightened somatic anxiety and self-confidence before competition.

In addition, it was hypothesized that both prior to training and competitive matches, left-side players will present lower levels of anxiety and higher levels of self-confidence when compared to right-side players. This was partially accepted, since left-side players only presented lower levels of somatic anxiety and state anxiety prior to training matches. As mentioned before, it is common in a padel pair consisting of right-handed players to position the best player on the left-side. This strategic choice is often made because it increases the likelihood of the player hitting more shots, especially overheads. It is worth highlighting that this is a pioneer study and future research should keep evaluating these trends.

It was also hypothesized that higher ranked players will show similar levels of anxiety and self-confidence between competition and training matches while lower ranked players will show lower levels of self-confidence and higher levels of anxiety before competition than training matches. The findings showed that among higher ranked players, somatic anxiety and self-confidence was higher prior to competition than before training matches. And, among lower ranked players, self-confidence was higher prior to competition than before training matches. The higher somatic anxiety observed among higher-ranked players before competition may be due to the fact that their performance is closely scrutinized, the stakes are higher, and there is an increased pressure to maintain their reputation and rankings, all of which contribute to a heightened arousal. This is consistent with findings from Cervantes Blásquez et al. (2009), who similarly observed higher somatic anxiety levels among athletes prior to competition compared to a simulated competition during training, as evidenced in their research with swimmers. For both the higher-and the lower-ranked players, the higher self-confidence before competition may be a result of the positive effects of pressure training. This is in accordance with Low et al. (2023), in which some international athletes were interviewed and admitted that their self-confidence was boosted due to the pressure training.

Additionally, it was hypothesized that match winning players will show similar levels of anxiety and self-confidence between competition and training while match losing players will show lower levels of self-confidence and higher levels of anxiety before competition than training matches. The results showed that there were significant differences only among winning players, in somatic anxiety and self-confidence. Specifically, these players presented higher values before competitive matches than before training matches. The pressure training conducted during the weeks leading up to the competition may have played a pivotal role in shaping the psychological preparedness of winning players (Gröpel and Mesagno, 2017; Kent et al., 2018). It is also worth noting that the positive effect of self-confidence on competitive success has been confirmed by several studies (Vealey and Greenleaf, 2001; Hassmén et al., 2004; Jekauc et al., 2023).

In a practical context, coaches are urged to engage in pressure training to enhance the readiness of their athletes for competitive situations (Stoker et al., 2016; Low et al., 2023). Similarly, it is recommended that athletes participate in psychological training to cultivate mental skills and effectively apply them under pressure (Lange-Smith et al., 2023). Moreover, coaches should consider psychological training to facilitate effective communication (Mora et al., 2009) with their players, conduct productive training sessions, and provide constructive feedback in both training and competitive environments.

This study possesses several notable strengths. Firstly, it marks the pioneering implementation of pressure training in the field of padel. Secondly, it stands as the inaugural research endeavor to examine precompetitive anxiety and self-confidence levels based on the side of play, as well as to compare precompetitive anxiety and self-confidence levels between players of the same side at the same

moment (pre-training and pre-match, respectively). Thirdly, the implications drawn from these findings hold substantial practical value for coaches and sport psychologists. It is imperative to consider these results in designing effective pressure training programs for athletes.

It is essential to underscore certain limitations inherent in this investigation. For future investigations, the implementation of randomized controlled trials in both genders is recommended to more accurately assess the impact of pressure training. Additionally, incorporating alternative tools like pulsometers, which measure heart rate variability, alongside traditional questionnaires would provide a more comprehensive understanding of precompetitive anxiety and self-confidence. Furthermore, expanding the participant pool to include both elite and amateur-level players is advisable for a more nuanced exploration of the psychological effects of pressure training in different players. Moreover, exploring the effects of pressure training on padel performance could provide a holistic understanding of the impact of this intervention on actual gameplay. In addition, it would be necessary to include the influence of left-handed players in this analysis in future studies.

Conclusion

The levels of anxiety and self-confidence before training matches and competitive matches have been described in high-level men's padel players from Finland who underwent pressure training in the two leading weeks to a competition. The analysis, accounting for variables such as side of play, ranking and match outcome, reveals distinctive patterns.

Pressure training exerts a discernible impact on players, manifesting in lower self-confidence and similar levels of cognitive and state anxiety, juxtaposed with elevated somatic anxiety before training matches when compared to competitive matches. This trend persists across left-side, higher-ranked and match winning players. Intriguingly, even lower-ranked players display heightened self-confidence ahead of competitions.

These findings offer valuable insights for players, coaches, and sports psychologists, enriching their understanding of the intricate interplay between pressure training, competition, and the athlete's psychological landscape. In practical terms, the results suggest that players can benefit from honing their mental skills and engaging in pressure training to optimize performance. Consequently, padel coaches are encouraged to consider psychological training, fostering effective support for their athletes. Hence, the incorporation of a sport psychologist within teams could prove instrumental in maximizing the psychological well-being and performance potential of padel players.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Ethics committee of the Universidad Europea de Madrid (CIPI/22.303). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

RC-R: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. AE-T: Supervision, Validation, Writing – original draft. ÁB-S: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

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Investigating the effect of grit trait on performance and success in Hungarian athlete's sample

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Background: The aim of the present study is to translate the Grit questionnaire into Hungarian and validate specifically within the context of sports. The second goal is to assess the questionnaire in Hungarian as a pilot study in the athlete population and to compare the grit trait with the coaches' athlete evaluation.

Methods: Two hundred and sixty nine athletes, including 40 national team players, took part in the study, with an average age of 18.17 years (SD = 5.51). For the preliminary assessment, the Cloninger Temperament and Character Questionnaire (TCI-RH) was used; the coaches' athlete evaluation was modeled on a talent map.

Results: The confirmatory factor analysis confirmed the fit of the two-factor structure, and the internal reliability of the questionnaire scales also proved to be adequate. 2. There is no relationship between adolescents' perceived grit and coach ratings. 3. The national team players achieved a higher grit score.

Conclusion: Based on the psychometric indicators, the validity and reliability of the questionnaire proved to be adequate. Therefore, it is applicable and useful for psychological practitioners and researchers in the Hungarian population within the context of sports.

KEYWORDS

sport psychology, adolescents, personality trait, perseverance, passion, long-term goals, grit

1 Introduction

One of the most fundamental and intriguing topics for professionals in the realm of any youth sports training system is finding the distinguishing psychological factors between prosperous and less successful players besides their physical capabilities - given that they undergo the same physical, tactical, and mental training - while identifying the players that possess the qualities to become professional athletes.

The study of the "grit" personality trait commenced in 2007 by Duckworth and colleagues, originating with the term's definition, and the subject has now evolved to be a widely researched topic in psychology. Duckworth and associates (Duckworth et al., 2007) defined grit as a non-cognitive trait that influences an individual's success and effectiveness through their committed perseverance toward long-term goals, sustained by passion even amid

prolonged adversity. In essence, grit is described as "perseverance and passion for long-term goals" (Duckworth et al., 2007, 1087).

The emergence of this trait, however, is not confined to the 21st century: its origins trace back to the research questions formulated by William James in 1907 [as cited in Duckworth et al. (2007)]. James sought an explanation regarding individual differences that determine success and effectiveness; specifically, what personality traits contribute to certain individuals achieving more and performing better than their peers. Duckworth et al. (2007) reported that some professions are associated with certain personality traits. For instance, extroversion is considered to be indispensable in a sales position, while for a writer, it is irrelevant. This line of reasoning continued with success, asserting that specific traits were imperative for success and high performance - such as the grit trait among prominent leaders, regardless of their field of expertise (Duckworth et al., 2007; Duckworth and Quinn, 2009; Fejes and Járai, 2018; Birr et al., 2023).

Sturman and Zappala-Piemme (2017) define grit as maintaining a focused effort to succeed in a task, regardless of the challenges and the failure to overcome them. The grittier individuals are characterized by the fact that while others easily give up when experiencing setbacks, they remain in the "ring" and pull through in the face of adversity until they reach their goal (Duckworth et al., 2007; Fejes and Járai, 2018). By determination and perseverance, they are able to keep up with their initially more successful peers (Duckworth et al., 2007; Kelly et al., 2014). The observations also showed that being talented is not enough: determination, thorough work, and practice are also key requirements.

In their publication from 2007, Duckworth and colleagues stated that grittier individuals tend to stand up and build on setbacks and challenges while others are more likely to abandon their efforts when they fail. Their reluctance, determination, and perseverance allow them to stay on par with their initially more successful peers (Duckworth et al., 2007; Kelly et al., 2014; Birr et al., 2023). In a more recent publication from 2016, Duckworth articulates that the grit trait is similar to any other personality trait: it is biologically and genetically predetermined to a certain extent and also shaped by environmental influences. In terms of grit, perseveranceis 37%, and passion is 20% inheritable, however there is no gene specifically responsible for this trait. Nature and upbringing determine the emphasis of the grit trait, which may manifest in various areas of life (Duckworth, 2016).

A variety of recent researches has confirmed that in the academic field, grit can also be applied to predict academic performance [grade point average (GPA)[1], Scholastic Aptitude Test (SAT)[2] or American College Test (ACT)][3] (Duckworth et al., 2007; Duckworth and Quinn, 2009); and retention in the areas of military training, marriage, and sales (Eskreis-Winkler et al., 2014) as cited in Sturman and Zappala-Piemme (2017).

Strayhorn (2014) as cited in Sturman and Zappala-Piemme (2017) also found that grit prediction exceeds the predictive capacity of college and graduate school GPA and the SAT/ACT results - as it provides a more accurate prognosis (4% - see Duckworth et al., 2007) concerning the results and success of an individual.

To sum up, grit has been studied extensively in a variety of achievement domains and has been consistently linked to success and an array of adaptive correlates. Although, the Grit Scale (english version) was only used recently in educational context in a Hungarian sample (Csizér et al., 2023). The main goal of our study was to fill a gap and investigate the factorial structure and measurement in variance, as well as the psychometric properties of the Grit scale in the Hungarian language and sports context. We aimed to validate the use of the Grit scale as a tool for coaches and sport psychologists, given that grit appears to play a crucial role for coaches when making decisions about talent identification and development in athletes (Tedesqui and Young, 2020).

1.1 Expert performance and deliberate practice

Researchers in sports tend to attribute elite performance to genetic talent. However, they do not offer comprehensive genetic descriptions that would determine the causal processes involved in the activation and expression of dormant genes in developing athletes during exercise, leading to the appearance of characteristic physiological and anatomical features (innate talent). Ericsson (2006a, 2007, 2009a) claims that the evolution of the elite performance of healthy children can be calculated without the use of unique talent (genetic endowment) - except for the innate determinants of body size. However, the anthropometric differences are not negligible, the success of an individual in athletics is strongly determined by how much their anthropometric characteristics are similar to elite players' athletic prowess. The determining role of physical properties varies by sport and it is important to note, for example, as encountered in basketball or handball, that one cannot limit athletic evaluation to only one anthropological model. It is imperative to establish separate models regarding different positions and genders (Rogulj et al., 2009). Significantly, fundamental differences about a player's size and proportion are closely aligned to the various positions. In basketball, guards are typically the shortest team members, centers are the tallest in both genders, and forwards are usually in between the two heights (Ziv and Lidor, 2009).

Besides the anthropometric differences, Ericsson's expert-performance approach shows that the distinctive characteristics of

1 GPA is a system used in high schools and universities, mainly in the US, to measure a student's performance and academic achievement. GPA is calculated by converting grades or percentages you receive for an assignment (A, B, C etc) to a corresponding point on the GPA scale. Most high schools and universities report grades on a 4.0 scale. The top grade A, equals a 4.0 (McCabe, 2023; https://www.timeshighereducation.com/student/advice/what-gpa).

2 SAT means *Scholastic Aptitude Test* or *Standard Assessment Task* and is widely used in college admissions in the United States, developed by the College Board. It measures mathematical and verbal reasoning (Wikipedia, 2024; https://en.wikipedia.org/wiki/SAT).

3 ACT means American College Testing is a standardized test used for college admissions in the United States. It measures 4 academic skill areas: English, mathematics, reading, and scientific reasoning [Wikipedia, 2024; https://en.wikipedia.org/wiki/ACT_(test)].

elite performers are adaptations to extended and intense practice activities that selectively activate dormant genes that all healthy children's DNA contains. The expert-performance approach has provided accounts for elite performance in several domains of expertise, such as music, ballet, chess, and medicine (Ericsson et al., 1993).

Ericsson in his theoretical framework explains expert performance as the result of individuals' prolonged efforts to improve performance while negotiating motivational and external constraints (Ericsson et al., 1993). In most domains of expertise, individuals begin their childhood with a regimen of effortful activities (deliberate practice) designed to optimize development. Even among elite performers, individual differences are closely related to the extent of deliberate practice. Research has found that engagement in deliberate practice is one of the best predictors of expert performance (Ericsson, 2006a). Deliberate practice refers to activities that require cognitive or physical effort, do not lead to immediate personal, social, or financial rewards, and are aimed at improving performance. Many characteristics once believed to reflect innate talent are the result of intense practice extended for a minimum of 10 years.

During the first phase of learning, novices try to understand the activity (Fitts, 1967), cited in Ericsson et al. (2009a). Ericsson calls this stage everyday activities/everyday skills depending on the experience-performance (see more: Ericsson, 1998, 90). In the middle phase of learning, the learners start to eliminate large mistakes and they no longer need to concentrate as hard to perform the task. After a limited period of training and experience—frequently less than 50 h for most recreational activities—an acceptable standard of performance is attained. Without further modifications and improvements, this typically leads to a stable plateau of performance as the performance is automated. With special practice, performance speed improves significantly across various domains, leading to notable changes in both cognitive and psychological capacities.

Ericsson's research shows that individuals who eventually reach expert levels of performance do not begin their training with an exceptional level of performance, nor do they suddenly attain extraordinary display of abilities at any stage of development (Bloom, 1985) cited by Ericsson et al. (2009a). The improvement of performance is gradual and generally takes several years of active pursuit to reach elite status. Even those who have historically been called "the most talented" usually do not win international competitions in less than a decade. Ericsson et al. (1993) stated that Simon and Chase's (1973) "10-year rule" is supported by data from a wide range of domains: music (Sosniak, 1985), mathematics (Gustin, 1985), tennis (Monsaas, 1985), swimming (Kalinowski, 1985), and long-distance running (Wallingford, 1975). Children, adolescents, and adults who are committed to achieving expert-level performance begin working with coaches and suggest new exercises that continue to challenge them and provide feedback on performance and opportunities to repeat the task (deliberate practice). Deliberate practice requires a focus on improving performance and involves two types of learning: improving one's existing skills and expanding the range and scope of one's abilities (Ericsson, 2009b). According to another definition, "deliberate practice, which was defined as engagement in structured activities created specifically to improve performance in a domain" (Macnamara et al., 2014, p. 1608).

Gladwell (2008) in his viral book called "Outliers" introduces the "10,000 h rule" based on Ericsson's theoretical work (Ericsson et al., 1993). Gladwell (2008, pp. 39–40) proposed that a minimum of practice hours was necessary and that this number was "the magic number for true expertise: 10, 000 h." It has been treated as evidence that amateurs usually only practiced up to 3 h a week in their childhood. By the time they reached the age of 20, there were 2,000 h of practice behind them. Professionals gradually increased the number of hours per week up to 3 h a day or 20 h per week of exercise over a 10-year time interval. It takes the brain time to assimilate what is needed for masterful performance (Ericsson et al., 1993, 2006b; Gladwell, 2008). Although Ericsson et al's. (1993) research showed that an extended period of training and practice was required to attain international-level performance, there was no evidence of a magical number. To win international piano competitions the first author estimated that around 25,000 h would be more accurate (Ericsson, 2013).

Ericsson's expert-performance approach has found ample evidence that children and adolescents do not spontaneously engage in the deliberate practice that ultimately leads to maximal performance. Consequently, children need help to identify the appropriate training activities, to learn how to concentrate, and to find the optimal training environments. An early introduction to instruction and supervised training in the domain is associated with a greater likelihood of reaching the highest levels in many different types of domains (Ericsson et al., 1993). However, the maximization of deliberate practice is neither short-lived nor simple. The theoretical framework of expert performance explains the apparent emergence of early talent by identifying factors that influence starting ages for training and the accumulated engagement in sustained deliberate practice, such as motivation, parental support, and access to the best training environments and teachers. Ericsson et al. (1993) highlights three limitations: the resource constraint, the motivational constraint and the effort constraint. To maximize gains from long-term practice, individuals must avoid exhaustion and must limit practice to an amount from which they can completely recover on a daily or weekly basis (Ericsson et al., 1993; Baker and Young, 2014).

Duckworth examined Ericsson's theory of practice (Ericsson and Pool, 2016) as cited in Duckworth (2016) and the grit trait, which concluded that grittier individuals not only learn more for Spelling Bee (Duckworth et al., 2011), the international spelling contest, but also have a higher GPA and tend to get better scores on standardized tests, such as the SAT or ACT. A noticeable difference in quality is also evident between contestants with varying placements (e.g.; Spelling Bee's top three vs. the others). The positive outcomes might be influenced by the tendency for people with higher levels of grit to engage in higher amounts of deliberate practice (Duckworth et al., 2011).

According to the scoping review of Cormier et al. (2021), several recent studies explored the relationship between grit and deliberate practice. In four cases, whole grit scores were positively correlated with hours spent in deliberate practice (Larkin et al., 2015; Tedesqui and Young, 2017, 2018; Fawver et al., 2020), while CI alone was significantly associated with the number of miles run per week in long-distance runners (Cousins et al., 2020).

Achieving world-class performance without spending 10,000 h developing, practicing, and immersing oneself in the field of interest is difficult and uncommon. Most people can only amass 10,000 h if they enter a particular training system or program. Passion, practice, goal, and hope are the keywords of grit. To help an individual reach

their goals, master their daily workout routine, to inspire and motivate them in a personalized way, they should create an effective talent program for youth training. Leaders must create an environment with excellent conditions, incorporate the know-how of experienced, professional teachers with cutting edge knowledge, and elaborate a training program of "hard and smart work." As for the development of the player, this means that they not only need to work consistently for a significant amount of time, but the quality of the work has a substantial impact on further success.

Smart work is always intellectual; it improves our innovative and creative thinking skills and enhances productivity. These special training systems must work by the principles of international excellence standards, innovative approach, and original know-how in addition to applying evidence-based, practical experience, long-term approach, and winning philosophy to incubate talents. In the field of sports, such talent programs may require various knowledge areas of vast complexity: talent identification system, players' performance assessment, training monitoring system, training program and periodization, recovery procedures, nutritional strategies, psychological care, injury prevention and rehabilitation system, the education of athletes about appropriate lifestyle and also the recruitment of performance people. In summary, the effectiveness of these systems depends on the individual approach to players according to their needs, the high volume of training ("smart and hard work"), the emphasis on training details, and the ability to build the "mindset of excellence," which is possibly linked to the concept of grit. It involves persistence, consistency, and resilience, which are integrative concepts of perseverance known as empowering personality traits (Akbag and Ümmet, 2017). Grittier athletes are able to stay focused and also tend to respond positively to feedback from coaches and teammates. High levels of grit may help protect athletes from negative self-evaluations and when receiving ego-involving feedback, as their focus is on skill improvement and maintaining their passion and long-term quest for the sport (Moles et al., 2017).

1.2 Previous result related to grit in sports context

Research interest on this subject has significantly intensified over the past decade. Despite the indispensable findings of Duckworth and colleagues in 2007, our initial understanding was limited to the relationship between the Big Five personality traits and grit (a moderately strong, positive correlation with conscientiousness), while today we know that grit correlates moderately strongly with hardiness. The perseverance of effort (PE) factor of grit also shows a moderate relationship with the commitment component of hardiness (Kelly et al., 2014). Elumaro's (2016) research revealed that grit was a predictor of sporting achievement while personality traits showed no significant differences.

Tedesqui and Young (2017, 2018) studied athletes' level of perseverance (one of the dimensions of grit) and they found that it's linked to the weekly quantity of deliberate practice, suggesting that individuals with high persistence cope better with the conditions of deliberate sports practice.

A study by Larkin et al. (2015) unveiled that among athletes participating in the Australian National Youth Soccer championship, those with a higher grit score showed greater sport-specific engagement (e.g., spending more time with training, racing, or in their free time, they have sports-related pastimes such as watching soccer matches or playing football in video games) in addition to having a better perceptual-cognitive performance (e.g., situational probability, pattern recognition, decision making).

Sellei's (2018) personality psychological work also addressed grit. She concluded that the higher grit score correlates with low parental criticism ($r = -0.333$), concern ($r = -0.209$), and doubt ($r = -0.315$). In her cognitive psychological work, Sellei (2017) focused on the pattern of GRIT and VAL in athletes' samples. The VAL value is a performance index used in basketball, which is described as "a player's complex, full-match performance" (Sellei, 2017, 8). Although there was no statistically supported correlation between these two indicators, it was found that grit had a marginal significance in predicting national team membership.

Research indicates that higher levels of grit are associated with a number of psychological factors in sports. Martin et al. (2015) found a positive relationship between grit and engagement in sports. According to the studies, grit is associated with a reduction in burnout levels (DeCouto et al., 2019), perceived life stressors (Ford et al., 2017), maladaptive perfectionism (Fawver et al., 2020) and lower levels of sport-specific anxiety (Symonds et al., 2018). Experiences of pride are also associated with grit, but only when success is attributed to one's own effort (Gilchrist et al., 2017). Crane et al. (2020) reported that lower levels of grit have been found to be associated with higher scores on general anxiety disorder measures. The grit subscales were also examined in sports context and the researchers found that CI and PE were both positively related to adaptive facets of sport-specific perfectionism, and inversely associated with maladaptive facets of sport-specific perfectionism (Dunn et al., 2021).

In the context of sports, Martin et al. (2015) related grit with commitment and staying in sports. From et al. (2020) reached a similar result as Fejes and Járai (2018). In their research examining athletes, they concluded that athletes achieved a higher grit score than non-athletes. From et al. (2020) focused on grit and conscientiousness in sports context because both traits have been connected to deliberate practice and performance (Barrick and Mount, 1991; Barrick et al., 2001; Ozer and Benet-Martínez, 2006; Duckworth et al., 2011; Eskreis-Winkler et al., 2014) and are highly related (Credé et al., 2017). They found that there was a high positive correlation between grit and conscientiousness and the elite athletes reported higher grit than the non-athletes control group (From et al., 2020). Reed and his colleagues (2012) investigated the relationship between grit, conscientiousness, and the transtheoretical model (TTM) of change for exercise behavior. The results showed that grit significantly predicted high-intensity and moderate-intensity exercise TTM stage while BFI Conscientiousness did not. The results suggest that grit is a potentially important differentiator of the TTM stage for moderate and high-intensity exercise (Reed et al., 2012).

According to the scoping review of Cormier et al. (2021), researchers examined differences in grit levels based on athlete sex and skill/competitive level. Several studies investigated the relationship between grit and sport performance and also examined relationships between grit and a variety of adaptive psychological constructs/characteristics and determinants of success in sport. It included relationships between grit and motivation, mindfulness, self-compassion, and deliberate practice. Sport researchers also assessed grit as it related to analogous personality characteristics including

hardiness, resilience, mental toughness, self-control, and conscientiousness (Cormier et al., 2021).

González-Hernández et al. (2019) investigated the possible link between dark personality traits, and unhealthy behaviors and grit, notably the association between exercise addiction and grit in athletes' sample. The results showed that the factor of Perseverance of Effort is positively correlated with addiction, and the other factor of grit, Consistency of Interests, did not present any kind of relationship. This seems to indicate that Perseverance of Effort is a trigger for addiction, while Consistency of Interests may help to self-regulate this behavior. In addition, younger athletes showed higher indicators of ambition to achieve their goals and a higher risk of exercise addiction, whereas gaining more experience with sports could facilitate the development of grit. In their other study (Nogueira et al., 2019), they strengthened this argument as the results showed that athlete men not only score higher for addiction levels but also narcissism (grandiosity feelings) and psychopathy (coldness) factors. They found that if signs of narcissism and Machiavellianism increase, perseverance of efforts grows too, and the likelihood of exercise addiction increases considerably. Consistency of interest appears as a protective factor, whereas Dark Traits of personality – especially Machiavellianism – constitute a risk factor.

Although grit has been consistently linked to adaptivity and healthy correlates, questions have been raised within the literature according to the conceptualization and measurement of grit. Credé et al. (2017) in their meta-analytic review of the grit literature found that the two dimensions that constitute grit, are the essential ingredients of success, assuming that perseverance of effort contributes to the achievement of excellence - despite failures and setbacks - and consistency in interests promote the commitment to deliberate practice in pursuit of the expert performance. According to their results, the higher order structure of grit was not confirmed, grit is only moderately correlated with performance and retention, and grit is very strongly correlated with conscientiousness. They found that the perseverance of effort facet has significantly stronger criterion validities than the consistency of interests facet and that perseverance of effort explains variance in academic performance even after controlling for conscientiousness. We have to mention that they also found inconsistencies in the assessment of the grit construct and they drew attention to the lack of confirmatory factor analyses to establish discriminant validity. They argue that the use of a general grit score might have limitations when it comes to predicting performance. Researchers have also found that the PE and CI subscales often have different relationships (and predictive power) with the same criterion variables – a finding that undermines the appropriateness of combining scores from the two subscales into a higher-order construct (e.g., Wolters and Hussain, 2015; Datu et al., 2017; Muenks et al., 2018).

Although one of the components of grit is perseverance, we have used it in a mainly positive context and we think there are circumstances in which it is maladaptive. (Datu and Fincham, 2021), cited in Birr et al. (2023) highlights that in circumstances where failure is inevitable, passion and persistence are not the right qualities to achieve success. Perseverance in the face of failures - whether repeated or unavoidable - can cause irreparable damage or loss. Therefore, blind persistence (Baumeister et al., 2003) cited in Birr et al. (2023) is not an optimal strategy when faced with tasks that cannot realistically be completed. This kind of persistence contradicts adaptability, since the individual is then unable to adapt his strategies to the situation, so it can show a negative correlation with consistency.

Taking the recent studies in sports context into account, grit was shown to be distinctive from other similar determinants of success such as hardiness, resilience, mental toughness, self-control, and in most of the studies, conscientiousness (Cormier et al., 2021). Conscientiousness, grit, and mindfulness strongly predicted resilience in sports context (Drury, 2019). Grit and self-regulation both share a positive relationship with resilience (Gupta and Sudhesh, 2019). It strengthens the argument that studies focusing on grit should continue and grit should be considered a useful and unique motivational tool by sport researchers.

1.3 Objectives and hypotheses

Several instruments are available to measure the grit personality trait, such as the 12-item Grit Scale (also known as Grit-O; see more Duckworth et al., 2007), the also 12-item Grit Scale for Children - GSCA (see more in Sturman and Zappala-Pierre, 2017) and the 8-item Grit-S (see Duckworth and Quinn, 2009). They were primarily available in English for measuring grit personality traits.

The main goal of our study was to examine the use of the grit scale in the sports context. We aimed to investigate the factorial structure and measurement invariance, as well as the psychometric properties of the Grit scale in the Hungarian language and sports context. We aimed to validate the use of the Grit scale as a tool for coaches and sports psychologists while we enhance the understanding of grit - as consistency of interests and perseverance of effort - and its role in sports performance and success.

The purpose of the present study is multi-faceted:

1 The adaptation of the original 12-item questionnaire into Hungarian as a pilot study for the sports population.
2 Comparing the athletes' self-evaluation on the Grit Scale with the aspects of the coaches' evaluation.
3 To verify the predictive power of grit regarding national team membership.

During the research, we assume that:

1 Grit Scale's translated Hungarian version will show a more accurate fit with the original Grit Scale than the one used in our previous research (see Fejes and Járai, 2018).
2 There is a positive correlation between the evaluation by the coaches and the evaluation by the athletes.
3 The athletes of the national team achieve a higher grit score than their teammates, who are not members of the national team.

2 Materials and methods

2.1 Grit scale

Based on the theoretical conceptualization of grit, a brief and independent measurement scale was developed: The Grit Scale (Duckworth et al., 2007). The original Grit Scale, which measures individual differences in grit through self-report questionnaires, consisted of 12 items. The distinction between the two dimensions of

grit [perseverance of effort (PE) and consistency of interests (CI)] is reflected in the subscales of the two primary self-report inventories used to measure grit: the Grit Scale (Duckworth et al., 2007) and the Short Grit Scale (Duckworth and Quinn, 2009) - both of which can be found on Angela Duckworth's homepage[4]. The Grit Scale (English version) was only used recently in an educational context in a Hungarian sample (Csizér et al., 2023). The main goal of our study was to fill a gap by translating, validating, and examining the use of the Grit scale in the sports context. Due to scientific comparability and the larger international sample available, we took a decision to translate and validate the original Grit Scale (Duckworth et al., 2007).

2.2 Coaches' athlete assessment

It should be considered that the grit personality trait did not have a significant relationship with the value of VAL – a performance index used and measured in basketball, which characterizes "a player's complex performance throughout the game" (Sellei, 2017, p. 8). There was no statistically supported correlation between these two phenomena: $r = 0.205$ $p = 0.199$.

We tried to examine grit and effectiveness from another approach. Previously, Duckworth et al. (2011) measured the relationship between grit and performance among the participants of the Spelling Bee competition in the US. The result clearly indicated that the grit trait affects performance, leading to better placement. We used this method in our previous research (see Fejes and Járai, 2018) - so we compared the grit score of the athletes with their best ranking. However, we did not get the expected results because, in the case of sports, we cannot speak of an integrated qualification system (e.g., National Championship vs. Preparatory Competitions), so we chose to use the talent map written by the Basketball Academy's specialists. In modern exercise and sports science, multiple methods are used to help experts identify talents and monitor their performance daily such as performance tests, motion analysis, collecting sensory data, etc. Coaches are also interested in statistics which analyze and rate the athletes as entities aligned with individual parameters. The talent map is a very simple method to summarize the test results and add the subjective assessment of an experienced coach who has been working with the player for a considerable time. "Our potential is one thing. What we do with it is quite another" (Duckworth, 2016, p. 14). The talent map describes the possible potential of the player. The talent map describes the possible potential of the player. It is necessary to add the subjective evaluation of the coach to the empirical data because, on the one hand, the unity of coach and athlete is essential and indispensable in sports: this includes the relationship and cooperation between them, as well as the meeting points, direction and goal of their motivation (Jowett and Ntoumanis, 2004; Kovács et al., 2021). On the other hand, acceleration as a phenomenon is common among youth athletes. In the case of young athletes, acceleration means faster-than-average growth and development. Because of the acceleration, they are taller, stronger, and more skilled than their peers. This can result in outlier performance, but only in that age group. However, the growth and development of their peers may catch up with them later, so the advantage caused by the acceleration disappears, and the sports results may lag (Balogh et al., 2015). Therefore the coach must be able to recognize and handle the accelerated condition, paying special attention to maintaining skills, motivation, and goals, and avoiding burnout. In the case of retarded or later-maturing athletes, the focus must be on maintaining motivation, providing development opportunities, maintaining self-confidence, and keeping them in the sport (e.g., if, compared to their teammates, the athlete is inferior in training or competitions, or in certain skills, the coach must know how to protect his athlete from premature dropping-out). According to this, grouping is based on the age group, gender, and level of talent. Players are divided among five categories, in which their coaches evaluate them and make predictions based on performance and ability. The most promising prospects are rated as players with international career opportunities, while the lowest-rated players are advised to change sports. Members of the national team receive the highest rating by default. Players are divided among five categories, in which their coaches evaluate them and make predictions based on performance and ability. The most promising prospects are rated as players with international career opportunities, while the lowest-rated players are advised to change sports. Members of the national team receive the highest rating by default. The map is created by the coach and the assistant coach in the pre-season period and supervised by the leader of the Academy. The map is dynamic and has to be discussed after the first half of the season (Rátgéber, 2017).

This method has been used at the Academy for several years.

The coaches were instructed to rate players on a scale from 1 to 5, based on their predicted potential:

1 A player with an international career opportunity
2 Potential to be a national team level player
3 1st class Hungarian player
4 Amateur level player
5 Change the sport

"A player with an international career opportunity" is the highest rank and designates players who stand out from their age group in all indicators such as anthropometric characteristics, practice and match performance, motivation, skills and abilities, as well as mental strength. Youth national team players are automatically given the highest rating. The national team player category is the second, which shows that the given young athlete has the potential to be included in the national team as an adult professional player. The Hungarian first-class player is the third category, they are still outstanding athletes in their age group, who can reach the level of adult professional players by staying on a straight development curve. The third category includes those players who are expected to reach the plateau phase sooner and are capable of average performance in the given sport, which is not enough to become an elite player. The lowest classification is given to the players who are among the weakest both physically and mentally, for them it is recommended to choose another sport.

2.3 The questionnaire translation procedure

According to the protocols for translating questionnaires (Harkness et al., 2004), the translation procedure of the original

4 https://sites.sas.upenn.edu/duckworth/pages/research

English version of the Grit Scale to Hungarian, in our study, is the following:

1 The original 12 items of the Grit Scale were translated by two, independent bilingual translators, both of whom are experienced in sport psychology.
2 The two translated versions of the 12 Hungarian items were harmonized by a committee of three members with expertise in sports psychology.
3 The final items selected by the committee were translated back to the English language.
4 Small refinements were administered to a few items after the back-translation procedure.
5 The final versions of the Hungarian translation of the original 12 items were ready for validity and reliability testing.
6 The back-translation process was made by the original translators and the three harmonizers independently.

Minor adjustments were made in Hungarian language on all of the items based on the slight differences between the translators and harmonizers on the one hand, and considering the respondent feedbacks on the other.

2.4 Participants

In our data collection, we gathered a database of 269 people. In the present cross-sectional study 269 athletes participated, with an average age of 18,17 years (the age range was 11–49 years; SD = 5.51), including 40 national team member athletes (average age of 23.07 years, SD = 4.39. Min.: 16 years max.: 38 years). 71.7% of the participants were male, 27.5% female, and 0.7% did not provide gender-related information. The majority of the roster was made up of primary or secondary school graduates. The athletes were participating in competitive sporting activities at an association/club; the national team member athletes - as the best of their age group - were individuals selected by the national federation of the sport and they were representing their country in international competitions, not a club. The sample included individual (e.g., badminton, pentathlon) and team sports (e.g., basketball, hockey, football) as well (see Figure 1).

2.5 Instruments

2.5.1 Grit questionnaire

All respondents ($N = 269$) completed the Hungarian version of the Grit Scale (Duckworth et al., 2007) (see Supplementary Appendix 9A), which assesses the perseverance of effort (perseverance of effort; PE) and the consistency of interest (consistency of interest; CI) with 12 statements. Participants were required to rate each item on a 5-point Likert scale: 1 = I am not like this at all.; 5 = I am totally like this. A higher score suggests a higher level of grit. Cronbach-alpha value of original questionnaire: 0.85.

2.5.2 Temperament and character inventory-55

In the shortened, 55-item Temperament and Character Inventory (TCI-55; Cloninger et al., 1993; Szabó et al., 2016), we used a dichotomous "true/false" response format (1 = true, 2 = not true). This personality questionnaire seeks to reveal the four temperaments and the three character factors (see Supplementary Appendix 9B). 113 athletes were subjected to the survey, of whom 29 were national team players, with an average age of 21.61 (SD = 6.19). 73.5% of the respondents were male, 23.1% female and 3.4% did not provide gender-related information. In terms of qualifications, nearly half of the participants had a high school diploma (43.6%), one-third of them were in elementary school (33.3%), and almost a quarter had a college or university degree (19.6%).

2.5.3 Coaches' athlete assessment

Coaches' athlete assessment was based on a basketball academy's selection system, which divided the players on a 5-point ordinal scale as follows: (1) player facing international career prospects; (2) player who has a possibility to become a national team member; (3) first-class Hungarian player; (4) amateur player; (5) sport change suggested.

Two coaches held this type of evaluation at a hockey association in Székesfehérvár.

2.5.4 Demographic data sheet

We had the participants fill out a data sheet, asking for general demographic information: gender, age, the types of sports they participate in, the way of competing (individual vs. team-based), and we asked almost half of the examined sample about their sport 'age' (since when did you play sports), national team membership and education (typically for athletes aged 16 or older). The obtained results are characterized by the average sporting age (12.31 years) of the interviewed athletes (SD = 5.49 years; min.: 1 year max.: 44 years).

2.6 Procedure

All psychological research involving human subjects must be preceded by careful assessment of predictable risks and burdens to the individuals and groups involved compared to foreseeable benefits to them and other individuals or groups affected by the condition under investigation. We took every precaution to protect the privacy of research subjects and the confidentiality of their personal information. To this end, prior to the study, we requested and obtained permission from the Hungarian Ethics Committee (ref. nr. 2019–101).

In our research involving human subjects capable of giving informed consent, each potential subject was adequately informed of the aims, methods, and institutional affiliations of the researcher. The possible subject was informed of the right to refuse to participate in the study or to withdraw consent to participate at any time without reprisal.

During the study, athletes who were evaluated by the coaches and athletes participating in the test–retest process were given codes, as we strived to maintain anonymity. This means that we are unable and unwilling to identify participants. These persons received the questionnaire with a code name, and then we stored them in an envelope before processing the data. The key and the recorded questionnaires are stored locked away at the Institute of Psychology, and the data stored on the computer is protected with a code. Due to the confidential and personally sensitive nature of the information contained herein, this report is not to be provided to third parties. Most importantly, athletes under 18 could only

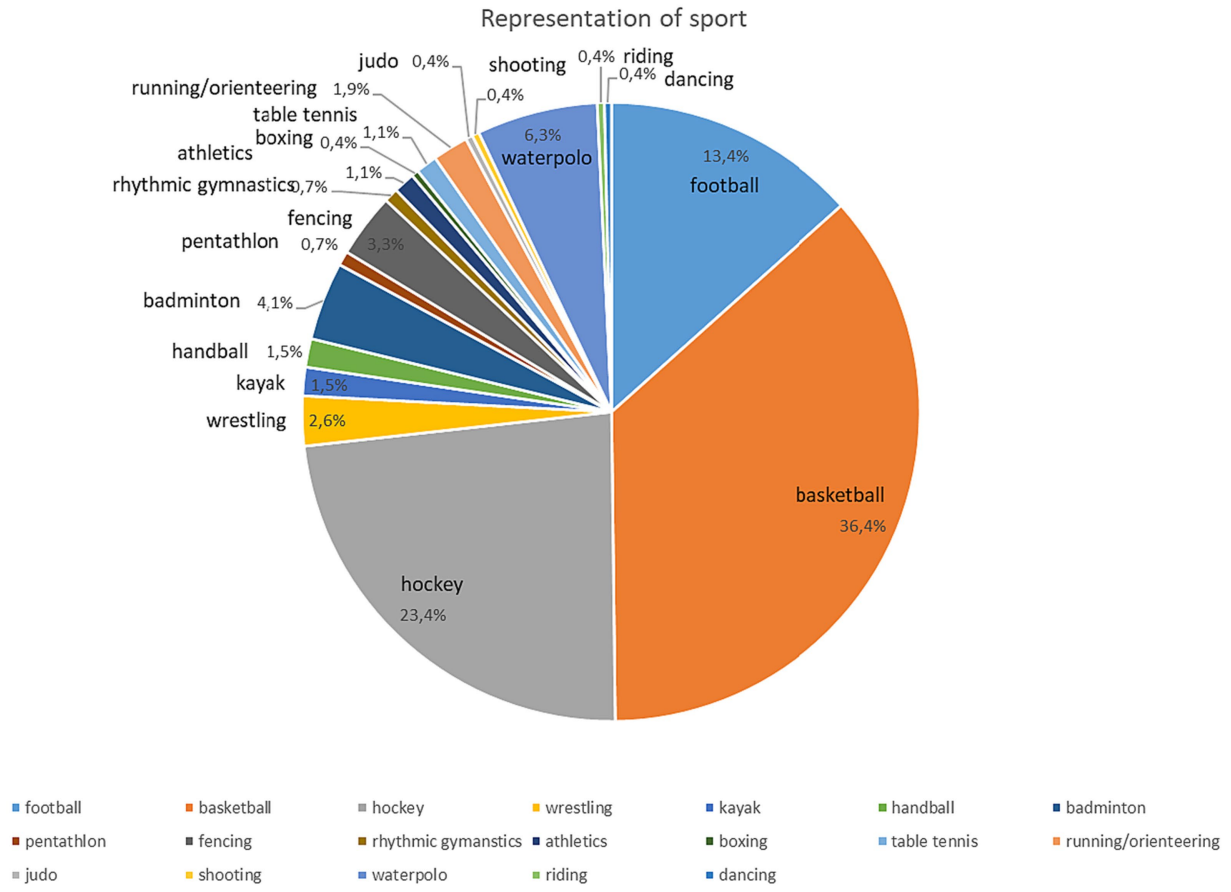

FIGURE 1
Representation of sports in the sample.

participate in the research with parental consent, which parents could sign up for by signing the section next to their child's name on a posted roster.

The procedure took place over several instances and locations/platforms. Athletes aged 18 and older completed the questionnaires online, in which the Grit Questionnaire ($N = 108$) and the TCI-RH ($N = 83$) were added to the demographic data sheet. 18% of these adult athletes participated in the test–retest procedure and filled out the questionnaire in person.

The participation of players in the 14–17 age group ($N = 161$) was based on a preliminary written information sheet and passive parental consent. This age group of individuals completed the test in person at an appointed time, in the halls of a given sports facility. The Grit Questionnaire and the demographic data sheet were also completed by this age group, and the coaches evaluated 60 players - but only 25 people were rated by 2 coaches. Other people (19% of adolescents') filled out the TCI-RH questionnaire in paper-pencil form, and 15% of these adolescents participated in the test–retest process.

To test the reliability of the Grit Questionnaire translated into the Hungarian language, we used the test–retest reliability, in which the number of participants was 42—between the first and second test sessions, 3 weeks passed. The data was anonymized and participation in this study was voluntary - as mentioned above. 113 athletes were subjected to this part of the survey, with an average age of 21.61 ($SD = 6.19$). 73.5% of the respondents were male, 23.1% female, and 3.4% did not provide gender-related information. In terms of qualifications, nearly half of the participants were attending secondary school (43.6%), one-third of them were in elementary school (33.3%), and almost a quarter had a college or university degree (19.6%).

We handled missing data and questions that were not answered by removing the incomplete tests from the sample. No data was entered in these cases. A total of three athletes dropped out of the sample because of missing answers.

3 Data analysis

The data was analyzed with the statistical software IBM SPSS v.22 the open-source statistical software Jamovi v.1.6.16[5], furthermore Microsoft Excel 2016. Factor structure was tested with the use of structural equation modeling (confirmatory factor analysis), with the use of the cut of values defined by Hu and Bentler (1998). Internal consistency was used to establish reliability with the use of Cronbach's alpha. Test–retest validity was investigated with the use of Spearman correlations due to the non-normal distributions of the observed variables. The possible

5 https://www.jamovi.org

differentiating role of grit was assessed by binary logistic regression with several effect size measures (McFadden, Cox-Snell, Naglerkerkes, odds ratio) and with the use of the Mann–Whitney U test. The possible connection of grit with other related constructs, as a form of convergent validity was tested by both correlation analysis and linear regressions, both of them with multiple effect site measures, Criterion validity was also tested with correlational techniques.

4 Results

4.1 Factor structure of the Hungarian version of the Grit scale (Grit-HU)

Confirmatory factor analysis (CFA) was applied to verify the proposed factor structure of the Grit Scale. In order to reconstruct the original design of the scale, we used a multilevel approach: two first-order factors (CI and PE) and one second-order factor (Grit) were included in our models. We proposed two alternatives: the first model (M1) included only the direct effects on the items to the first ordered factors and after the impact of CI and PE on the Grit. In contrast, in the second model (M2), three residual covariance relationships were applied between the items (see Figure 2). Based on Hu and Bentler (1998), according to the analysis results, M2 yielded satisfactory fit indices (see Supplementary Appendix Table A1), therefore, we accepted it as our final model. The Grit Scale's Hungarian factor structure proved to be primarily similar to the original version with two significant changes: the fourth item ("Setbacks do not discourage me.") and the seventh item ("I often set a goal but later choose to pursue a different one.") showed no significant loading to any of the factors. Consequently, we chose not to involve them in evaluating the factors and the total score of the Grit Scale. These changes also indicate that in the following analyses, we used the means of the items of the factors and the full scale to ensure the extensive comparability of our results. To summarize our findings, the applied CFA provided a similar factor structure in the case of the Hungarian version of the Grit Scale (Grit-HU) with some relevant modifications.

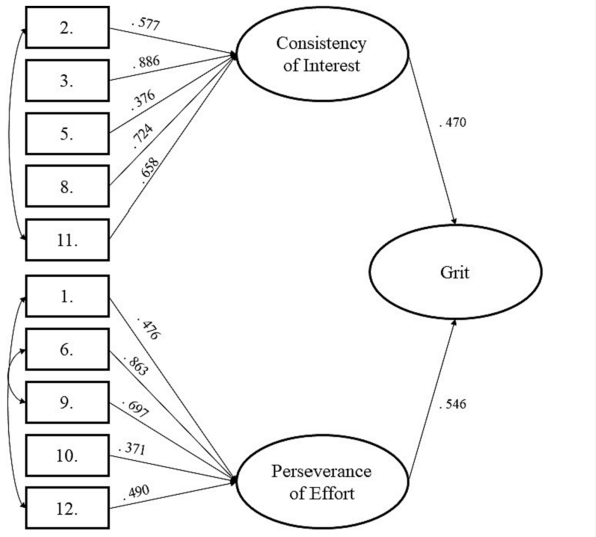

FIGURE 2
Confirmatory factor analysis of Grit-HU.

4.2 Reliability of the Grit-HU

Two approaches of reliability analysis were applied to verify the structural and temporal stability of the scale. First, we used an internal consistency analysis employing the estimation of Cronbach's alpha values. The internal consistency was found to be questionable in the case of PE ($a = 0.682$; CI: 0.612–0.734), and acceptable concerning both the CI ($a = 0.768$; CI: 0.721–0.808) and the whole scale ($a = 0.741$; CI: 0.710–0.792). Based on Fornell and Larcker (1981) and Kline (2000) values above 0.7 indicate good reliability, the Hungarian version of the Grit Scale's (Grit-HU) internal consistency is most acceptable for assessing grit and its components.

As another approach to testing reliability, we conducted a test–retest reliability analysis. The Spearman correlations between the first ($N = 265$) and second ($N = 42$) conducting of the Grit-HU (which happened 3 weeks apart) were identified as follows: CI: 0,628; $p < 0.001$; PE: 0,642; $p < 0.001$; Grit-HU: 0,699; $p < 0.001$. The results indicate a moderately strong positive connection between the two instances of the grit assessment with the Grit-HU. As a result, its temporal stability is reasonably acceptable.

4.3 The divergent validity of the Grit-HU

The divergent validity of the Grit-HU was tested by binary logistic regression, in which we investigated the unprecedented power of the cumulated grit score between national team athletes and non-national team athletes. We assume that these two groups are fundamentally different from each other on a latent dimension that assesses general performance, therefore we use it in a nominal transformation to assess the possible differentiating role of grit. The results of the analysis supported the role of grit in this differential process: the hypothetical model was significant ($\chi^2 = 4.704$; $p < 0.05$), although its explained variance was relatively low (McFadden $R^2 = 0.027$; Cox-Snell R2 = 0.031; Nagelkerke $R^2 = 0.045$). Grit emerged as a significant predictor with a prominent effect size (OR = 2,524; $p < 0.05$). Based on Campbell and Fiske (1959), the divergent validity of the Grit-HUwas supported.

The Mann–Whitney *U* test was also performed in order to measure the divergent validity of the Grit-HU. In the case of the factors, none of them showed significant differences between the groups of national team athletes and non-national team athletes (CI → U = 1831.500; $p = 0.100$; rrb = 0.175; PE → U = 1888.000; $p = 0.159$; rrb = 0.150), although the total score of Grit HU proved to be significant (Grit HU → U = 1681.000; $p < 0.05$; rrb = 0.236), where national team athletes ($M = 4,155$; SD = 0,419) showcased a higher level of grit than non-national team athletes ($M = 3,975$; SD = 0,476) with a medium-weak level of effect. Based on Mann and Whitney (1947) and Campbell and Fiske (1959), the divergent validity of the Grit-HU was supported again.

4.4 The convergent validity of the Grit-HU

The convergent validity of Grit-HU was tested with (1) correlational analysis and (2) linear regression analysis along the factors of TCI-55. The correlational analysis showed significant connections between Grit-HU, (1) Persistence, and (2) Self-Directedness. In the case of the composite score of grit, persistence showed a medium-high correlation, while Self-Directedness had a

medium-low connection. While Consistency of Interest displayed a medium-low correlational relationship with Persistence and Self-Directedness, Perseverance of Effort showed a medium-high connection with persistence and a medium-low with Self-Directedness (see Supplementary Appendix Table A2).

The linear regression analysis revealed that the most considerable predictive power of Persistence and Self-Directedness appeared in the case of Perseverance of Effort and the lowest in the investigation of Consistency of Interest. The standardized coefficients were significant; their effect size ranged from weak to medium (see Supplementary Appendix Table A3). These findings highlight that the convergent validity of the Grit-HU is supported, based on Campbell and Fiske (1959).

4.5 The criterion validity of the Grit-HU

The criterion validity of Grit-HU was tested by correlational analysis with the use of personal evaluations about the participants provided by two external experts in the field. The experts used a five-point Likert-type scale (where the higher scores indicated the perceived performance) to express their opinions about the participants individually. We used the mean of the scores given by the experts, where no significant correlations were found neither in the case of Grit-HU ($rs = 0.101$; $p = 0.638$); nor regarding Perseverance of Effort ($rs = 0.353$; $p = 0.083$) or Consistency of Interest ($rs = 0.001$; $p = 0.991$). Based on Corder and Foreman (2014) and these results, the evaluation by the experts did not support the criterion validity of the Grit-HU and its subscales. In the Discussion section, we provide further interpretation for these findings.

4.6 Additional results

In this research we also aimed to investigate grittiness according to age groups, for which the age groups were formed from the point of view of developmental psychology. The difference between the age groups (adolescent: 12–18 years; young adult: 19–25 years; adult: 26+) was tested using the Kruskal-Wallis test, which is as follows:

- There was a significant difference between the CI factor scores of the adolescent and adult categories $\chi^2(2) = 8.537$ $p = 0.014$ and the average grit scores: $\chi^2(2) = 12.163$ $p = 0.002$. In the case of the scores achieved on the PE factor, there was a marginally significant difference between these two age groups: $\chi^2(2) = 5.633$ $p = 0.060$.
- Two other age group comparisons (adolescent vs. young adult; adult vs. adult) did not show statistically verifiable differences either in the case of PE-, CI-, or the total grit score. However, an increase in average scores can be observed (see Supplementary Appendix Table A4) in the increase according to age groups (see Figure 3).

5 Discussion

The structure of the Grit-HU - two correlated dimensions - showed a good fit with the dimensions of the original English-language Grit Scale (Duckworth et al., 2007) after removing two items (the fourth item: "Setbacks do not discourage me." and the seventh item: "I often set a goal but later choose to pursue a different one"). As can be seen, during the confirmatory factor analysis (CFA) of the Grit-HU questionnaire, other items showed no significant loading to any of the factors than the items of the Short Grit Scale (Duckworth and Quinn, 2009). The 2 items mentioned earlier can be found in the Short Grit Scale. That is why it is also appropriate that we used the original 12-item grit scale, so there was a greater opportunity to examine the characteristics of the sample of Hungarian athletes when measuring the characteristics of grit.

However, an interesting result is that in Birr et al's. (2023) work, the dropped out item is the same as one of the items that did not show a significant relationship in our case ("Setbacks do not discourage me"). When they measured the Grit-S questionnaire on a sample of Portuguese athletes. This was explained by the fact that this item focuses more on grit than on one of the components of grit, persistence. We would add to this that this item also contains a kind of emotional component, which is equally true and appears in athletes as well - especially in case of losing a major match or ranking - and they experience failure or loss in the same way. Only with a solution-oriented, positive attitude, struggle, will, perseverance, passion, and goal orientation can they overcome these more easily and continue on their way to achieving their goals (this could be the reason why the item does not load well). At the same time, cultural differences and views should not be ignored, which can also explain why certain items work well in one nation and why they do not.Its internal reliability also proved to be acceptable. Therefore, in the Hungarian version of Grit Scale (GRIT-HU), we found 10 items that are related to the measured variables in accordance with the original factor structure, so only these were taken into account to calculate the total score, but in anticipation of further research, we were left with all 12 items in the adaptation of the test (Table 1).

The Grit-HU Questionnaire dimensions were proven for persistence (P) and self-directing (S), based on the fitting directional and strong correlations of the TCI-RH dimensions. Thus, Hypothesis 1 is also supported, as not only is the fit reliable but also the validation of the measured Grit dimensions with TCI-RH proves that perseverance of effort (PE) and consistency of interest (CI) are indeed measures of perseverance and self-direction. This is hardly a surprising result, partly because the aforementioned earlier studies have already proven that athletes are persistent and steady; striving with diligence and unwavering commitment in pursuit of their self-defined aspirations (Duckworth et al., 2007; Kelly et al., 2014; Larkin et al., 2015) (Table 2).

In addition, persistence is one of the essential cornerstones of grit, besides determination with passion and long-term goals. Self-control (S) has previously associated with grit as a component of conscientiousness (Duckworth et al., 2007). Similar to the character scale, high achievers are characterized by reliability, trustworthiness, responsibility, and awareness. Such individuals tend to adjust their lives to their goals, giving them meaning and direction. They are long-term thinkers, who demonstrate efficacy and treat emerging situations as challenges while aspiring to make the most of themselves (Mirnics, 2006). These enumerations are very close to the description of the grit trait, thus confirming the significant association between them (Table 3).

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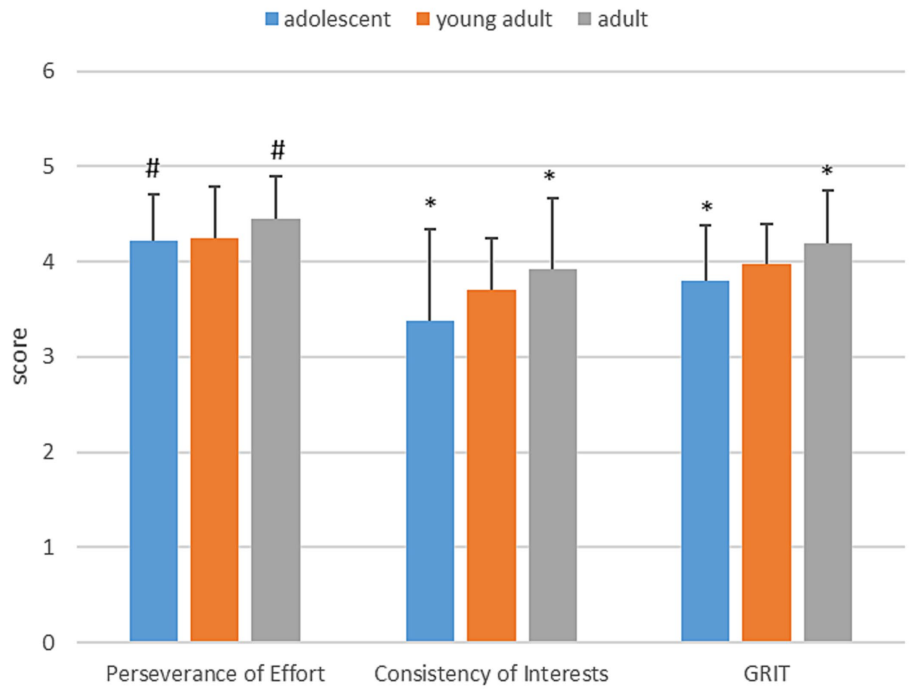

FIGURE 3
Evolution of average values and standard deviations by age group. * means a significant difference between adolescent and adult, where $p < 0.05$; # means a marginally significant difference between adolescent and adult, where $0.1 > p > 0.05$.

TABLE 1 Fit indices of the proposed models.

	χ^2	df	CMIN/df	CFI	TLI	NFI	RMSEA	GFI	MFI	AIC	BIC
M1	63.461	33	1.923	0.949	0.931	0.902	0.059	0.954	0.943	6587.107	6665.526
M2	52.949	31	1.708	0.964	0.947	0.918	0.052	0.962	0.959	6580.594	6666.143

χ^2, Chi-square value; df, degrees of freedom; CMIN/df, the quotient of the Chi-square value and the degrees of freedom; CFI, comparative fit index; TLI, Tucker-Lewis index; NFI, normed fit index; RMSEA, root mean square error of approximation; GFI, goodness of fit index; MFI, McDonald fit index; AIC, Akaike information criterion; BIC, Bayes information criterion.

5.1 Coaches' athlete assessment and grit by age groups

There was no statistically verifiable relationship between the talent map based coach's evaluation of the Basketball Academy and the athletes' self-reported grit results. Thus, the examined hypothesis 2 emerged as unproven in our research. This may have been caused by several factors. Coaches' evaluations, as described in section 2.3, are grounded in the time of joint work between coach and athlete - whether it be a shorter or longer period - during which the coach gets to know his athlete. During this period, performance may fluctuate, therefore it is generally recognized that the assessment of a season cannot be considered reliable in itself, as many external and internal factors can affect the performance of average people and athletes as well. For example, a sudden injury, illness, or in some instances even a slower adaptation process might occur, if the player is away from home court, is being transferred (new environment, new hall), or if they are adapting to a new playing position. The coach's evaluation also raises the issue of subjectivity. In the current study, for each athlete ($N = 25$), we asked two specialist coaches whose rating was 99% consistent. On the other hand, we cannot ignore the fact that we had no insight into how the evaluation was conducted, whether there was an event level or personal comparison (e.g., performance in a major competition or a more skilled teammate) when categorizing athletes. We could not find the connection between grit and the talent map that should show the possible potential of the players. As the talent map is a dynamic tool with regular revision, probably it would be more accurate to use it in longitudinal studies that span several seasons, linked with the appearance and changes of grit. Furthermore, we should not overlook the fact that the coach-athlete relationship might distort the judgment even of the most objective individual. In self-reporting tests, there is always potential for bias and it is more likely that the extent of the ability for insight and self-reflection is reduced.

We consider it a significant result that, when comparing the age groups, we obtained a significant result between adolescents (12–18 years) and adults (26+ years) regarding both the subscales (PE and CI) and the grit total score. From this we cannot yet conclude that grit scores increase with advancing age, however, since there was a statistically verifiable difference between the two extreme groups,

TABLE 2 Correlation matrix of Grit-HU and TCI.

	1	2	3	4	5	6	7	8	9
1. Grit-HU	—								
2. Consistency of interest	0.870***	—							
3. Perseverance of effort	0.838***	0.460***	—						
4. Harm avoidance	−0.040	0.014	−0.100	—					
5. Novelty seeking	−0.103	−0.117	−0.069	−0.085	—				
5. Reward dependence	0.096	0.090	0.069	0.093	0.141	—			
6. Persistence	0.523***	0.302**	0.577***	−0.238*	−0.191*	−0.012	—		
7. Self-directedness	0.308**	0.294**	0.298**	−0.190*	−0.046	−0.102	0.205*	—	
8. Cooperativeness	0.076	0.090	0.160	0.013	−0.070	0.133	0.025	0.263*	—
9. Self-transcendence	0.088	−0.039	0.185	−0.145	0.206*	0.217*	0.125	−0.249*	−0.025

$p < 0.05$; $p < 0.01$; $p < 0.001$.

TABLE 3 Linear regression connections among Grit-HU (and its factors), perseverance and self-directedness.

	R	R^2	aR^2	AIC	BIC	RMSE	*F* (df1; df2)	*p*	*P*	P_p	S	S_p
Grit	0.559	0.312	0.299	086.330	097.168	0.344	34.503 (2,108)	<0,001	0.478	<0.001	0.202	<0.050
CI	0.385	0.148	0.132	166.097	176.971	0.490	09.471 (2,109)	<0,001	0.253	<0.010	0.243	<0,010
PE	0.603	0.363	0.352	102.791	113.665	0.369	31.101 (2,109)	<0,001	0.382	<0.001	0.166	<0.050

R, explained variance; R^2, square of explained variance; aR^2, adjusted square of explained variance; AIC, akaike information criterion; BIC, Bayes information criterion; RMSE, root mean square error; Grit, Grit Hu; CI, consistency of interest; PE, perseverance of effort; *P*, persistence; *S*, self-directedness; values under "*P*" and "*S*" are standardized regression coefficients, "P_p" and "S_p" are the consecutive *p*-values.

we can say that the development of underlying skills and abilities with advancing age has an impact on the level of grit scores (Peña and Duckworth, 2018). During the sensitive period of 12–18 years, individuals undergo dramatic cognitive and physical changes while forming ever-evolving social expectations. For that reason, they paint a more realistic picture of themselves in late adolescence (17–18 years), utilizing the fundamental skills, experiences, and boundaries they have obtained (Robins and Trzesniewski, 2005; Turner and Reynolds, 2012; Duckworth, 2016; Peña and Duckworth, 2018). Likewise, the realization of the future self (Robins and Trzesniewski, 2005; Turner and Reynolds, 2012) helps to formulate and set more refined goals (ideas, philosophies, ideologies), which guide our lives and also play an essential role in the development of the grit trait (Duckworth, 2016). Taking this into account, it becomes evident that there is a tendency for higher grit scores as age progresses - as Duckworth et al. (2007), cited by Peña and Duckworth (2018) and Credé et al. (2017), cited by Peña and Duckworth (2018) have already verified between grit scores and age in adulthood in cross-sectional studies. In our study, adults (26+ years) tend to score higher than young adults (19–25 years), while adolescents (12–18 years) typically achieve the lowest points among these age groups. As Birr et al. (2023, p. 10) say, "In fact, with young athletes, considering their psychosocial development, athletic identity must be coordinated with other identities, adaptability is key and profiles with high perseverance and low consistency may occur" (Table 4).

5.2 National team

We investigated the relationship between national team membership and grit among the selected athletes, to confirm the focus of Sellei's research in 2017. Consequently, particular emphasis was placed on the selection of athletes within the sampling process. We surveyed 150 athletes to inquire about their past and current selection status and 40 respondents confirmed being selected at some point. This non-proportional distribution also showed that national team member athletes score higher on the grit average than non-national team member athletes. After concluding the survey, we examined whether grit can be utilized to predict the likelihood of an individual becoming a national team member. In the Results section, we can see that this indicator is 4.5%, aligning closely with the 4% measured by Duckworth et al. (2007), confirming our hypothesis 3.

6 Conclusion

The objective of the present study encompassed the analysis of the Grit-HU Questionnaire on an athlete population, comparing the grit trait with the coach's evaluation, in addition to assessing the predictive power of grit in terms of an athlete's likelihood of being selected for the national team. The obtained results suggest that, according to the psychometric indicators, the questionnaire demonstrates adequate

TABLE 4 Average scores with standard deviation values by age group.

		Perseverance of effort		Consistency of interests		GRIT	
	N	Mean	Std. deviation	Mean	Std. deviation	Mean	Std. deviation
Adolescent	174	4.2175	0.49270	3.3753	0.96451	3.7958	0.58044
Young adult	72	4.2444	0.54460	3.70000	0.54021	3.9722	0.42167
Adult	22	4.4545	0.44156	3.9273	0.73691	4.1909	0.55713

validity and reliability. In our study, we used a multilevel approach: the first model (M1) includes only the direct effects on the items for the first-order factors, and then the effects of CI and PE on the particles. In the second model (M2) we used three residual covariance correlations between the items. M2 yielded satisfactory fit indices, therefore we accepted it as our final model which is why we chose this as our final model. This model confirms the assumption that the grit trait is a multifactorial concept. From a practical point of view, if we want to strengthen or develop grit in an individual, we need to grasp the components that have a direction through interests; and the amount of energy invested by effort. What both components have in common: focus and organization. These skills can be part of the skill palette of the grit trait.

Secondly, the self-reporting Grit-HU Questionnaire cannot be compared with the coach's evaluation it is based on other criteria. Lastly, national team athletes achieve a higher average score on the measured Grit dimensions than their non-national team counterparts, which solidifies the predictive power of grit at 4.5% for national team qualification, as compared to the 4% measured by Duckworth et al. (2007). As a result, the phenomena examined in this research further expand the knowledge about the personality trait of grit, thereby enriching the colorful palette of the positive returns it yields. Researchers are trying to reinvent the Grit Scale with several models (e.g.: GSCA, Academic Grit Scale, PE-Grit), often by adapting to the specifics of their research field. Clark and Malecki (2019) created the Academic Grit Scale specialized to the field of pedagogy; Schimschal et al. (2022) designed the Grit Psychological Resources Scale in the nursing environment; Zhang et al. (2023) developed the Physical Education Grit Scale, in which model they separate academic "grit" from athletic "grit," trying to distinguish between the grit that appears in different fields. These attempts point in the direction that each research field would require a specific version of the grit scale.

However, along the lines of these efforts, we deviate from the fact that grit is field-specific, grit generally helps the individual to achieve outstanding results, and the effect of grit can appear, e.g., in music, and school performance (Duckworth et al., 2007). Our current research also tries to point out that the original 12-item Grit Scale, similar to Shaban (2020), shows a suitable fit, and produces adequate results in terms of measurement, so it can be applied to the sample of athletes as well, from adolescence onwards. Keeping this model and factor structure, we would like to contribute to the possibility of an international comparison of the Grit Scale. Referring to the model fit statistics described by Birr et al. (2023), regarding the future of research and the Grit-HU Questionnaire, as further direction we consider measurements with the Short Grit Scale on a sample of Hungarian athletes.

Given that grit appears to be very useful for coaches when making decisions about talent identification and development in athletes (Tedesqui and Young, 2020) and also that grit is a trait that can be developed (Bashant, 2014; Duckworth, 2016), our study can provide a distinctive utility to researchers and practitioners. Grit-HU can provide important help in identifying features of the athletes that could affect their involvement in sports. Measuring grit can be a potential contribution to raising the attention of coaches about the impact of these variables on the behavior of the athletes helping them to promote passion and consistency. Research findings revealed that grit is a statistically significant predictor of subjective well-being (Akbag and Ümmet, 2017). Overall, focusing on grit is not only important from the point of view of sports success but can be crucial for the mental health of athletes. In addition, it should be noted that the sports environment is a very complex area (Birr et al., 2023). Almost every sport has various characteristics (e.g., from what age can you start, when is the retirement age, what is the competition system like, etc.) these can influence the development of personality and the development of specific abilities as well (Cormier et al., 2021; Birr et al., 2023), therefore it is essential to start longitudinal studies to measure the development of grit personality trait in an athlete population.

Future directions include the amelioration of the Grit-HU for athletes, as well as the implementation of novel interventions by coaches and sport psychologists that may improve athlete grit. We also recommend that research and practical colleagues in the field of sports psychology start research on grit in the future, since the preservation and protection of the athletes' physical and mental health not only affect the coaching duties, but are also part of the sports psychology work.

7 Limitations

First of all, the sample size is large, close to 300 people, but for an even more accurate measurement, it will be necessary to expand the number of employees in the future and include even more athletes - in both individual and team sports, as well as national team members. The sample of elite and young athletes included many different sports. While this heterogeneity and wide immersion support generalizations and validation in the sports context, it may also mask possible differences across sports. Future studies could examine possible differences in the predictive value of grit across sports domains. Furthermore, the number of athletes who were evaluated by 2 coaches is very low. It is important to increase this number of elements to approximately 100 people and conduct the evaluation for at least 2 seasons to observe the changes. Thirdly, considering the future of research, it would be worthwhile to include the examination of the coach-athlete relationship. These duos have a lot of power (Jowett and Ntoumanis, 2004; Kovács et al., 2021) that can either benefit or hinder the detection of grit. The work between coach and athlete includes

getting to know each other, being attuned to each other, working, and fitting in. These factors can greatly influence the extent to which an athlete can show their innermost core of personality, which includes grit (comp.: manifested vs. latent), and the extent to which a coach can see this even when it is not yet manifested.

Data availability statement

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

Ethics statement

The studies involving humans were approved by the PTE BTK-Egyesített Pszichológiai Kutatásetikai Bizottság (United Committee on Psychological Research Ethics of University of Pécs). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

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

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1283115/full#supplementary-material

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The influence of "momentum" on the game outcome while controlling for game types in basketball

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In competitive sports, momentum encompasses positive or negative changes in cognition, physiology, emotions, and behavior caused by sudden or a series of continuous events. Momentum occurring during basketball games leads to significant performance variation regarding positive net points differences for a specific team within a certain period. This study designed a quantitative framework based on two performative dimensions (time constraints and point differentials) to accurately identify momentum in basketball games, and explored the role of momentum in games. We identified 2,083 momentum occurrences in 372 professional elite basketball games. The number of momentum occurrences for winning teams is significantly higher than for losing teams (1.78 ± 0.47 Difference Value, $p < 0.001$); the correlation between momentum and game outcomes decreased as each quarter progressed. To distinguish the influence of contextual variables on momentum, we divided games into five types based on the team quality differences between the team and the opponent team. The decision tree model shows that first-quarter momentum is critical in games where weaker teams defeat stronger teams. This study provides insights for basketball coaches to formulate game strategies. More importantly, the momentum conceptual framework can help researchers identify and capture momentum, offering inspiration and reference for subsequent research.

KEYWORDS

momentum, sports performance analysis, winning factors, basketball, phenomenology

1 Introduction

In competitive sports, the factors of winning have always been the focus of sports science. Previous studies have not only updated and enhanced our understanding of the fundamental rules of competitive sports from a theoretical perspective, but have also provided practical decision-making advice and training guidance for coaches and athletes. Basketball, a team sport involving on-court confrontation, is influenced by multiple factors affecting the game results (Brand et al., 2006; Gómez et al., 2008, 2011; Mikołajec et al., 2021). To comprehensively analyze the complex structure behind basketball game results, we need to consider the overall performance of both teams from both the offensive and defensive perspectives. Scoring and conceding points, as the most direct indicators of offensive and defensive effectiveness, are not

only the final outcomes of all tactical performances but also the focus of competition between the two teams. However, scoring behavior is a dynamic, random, and non-linear complex process, with the frequency of scoring and the probability of consecutive scores being even more difficult to predict (Gabel and Redner, 2012; De Saá Guerra et al., 2013). Many researchers have attempted to understand the relationship between sports performance and game results by investigating the relationship between scoring and game context or by combining other performance indicators (Bar-Eli and Tractinsky, 2000; Sampaio et al., 2010b; Gómez et al., 2011, 2019).

Momentum is a scoring-related phenomenon in competitions; it is widely discussed by researchers with various definitions. Its manifestations in games include the "hot hand effect" (Gilovich et al., 1985; Koehler and Conley, 2003) and "winning streaks" (Salaga and Brown, 2018; Munoz et al., 2019). These different manifestations are based on various research subjects, focusing on different aspects, but they all share one common conclusion: momentum can alter individual and collective behavior. For example, the hot hand effect can influence players' shot selection and coaches' substitution strategies (Attali, 2013), and enhance athletes' game performance (Zhao and Zhang, 2023). Further, scoring streaks can make athletes more positive, thereby improving their performance (Palmer et al., 2022). This evidence appears to prove one conclusion: in sports competition, success leads to further success. Momentum is a widespread phenomenon in sports competitions, but observed anomalous performances lack a unified concept or research framework. Even random processes like coin tossing can occasionally exhibit long winning streaks. Therefore, the anomalous performance of athletes or teams may also represent pure statistical probability (Bar-Eli et al., 2006; O'Donoghue and Brown, 2009).

The theoretical concept of momentum can be traced back to Adler's serial conceptual model involving social action, where the sequential activation of motivation, emotion, and physiological arousal aims to enhance performance (Adler, 1981). Based on this theory, researchers in the field of sports psychology have internalized momentum as a psychological force that changes behavior and performance (Iso-Ahola and Blanchard, 1986; Taylor and Demick, 1994; Iso-Ahola and Dotson, 2016). Momentum is also viewed as a mediating phenomenon explaining the relationship between early success and subsequent success; it is a composite process and complex phenomenon involving psychological, physiological, and behavioral variables (Briki, 2017). Although momentum is the focus of several sociological and psychological studies, it also faces some skepticism, it is considered helpful for task completion but does not necessarily affect game outcomes (Gilovich et al., 1985; Koehler and Conley, 2003; Bar-Eli et al., 2006).

Whether in the field of sports performance or sports psychology, analyzing the role of momentum in achieving victory in sports competitions requires the ability to accurately capture momentum in games. Researchers have found that momentum is a concept that is difficult to quantify, and its ambiguous nature makes it challenging to accurately identify momentum in live games or game data (Moesch et al., 2014; Briki, 2017). Moreover, a controversy exists as to whether momentum is real or an illusion (Cotterill, 2012). Researchers have attempted to capture momentum through surveys and interviews with individual players and coaches, subjective feelings, and by observing game videos (Vallerand et al., 1988; Mace et al., 1992; Burke et al., 1997; Moesch and Apitzsch, 2012; Moesch et al., 2014). However, the fast-paced and ever-changing nature of basketball games makes it difficult to determine whether a team's offensive or defensive performance has improved in short-term (Gómez et al., 2011). The statistical analysis of the sequence of game events is more objective and accurate (Mortimer and Burt, 2014; Csapo et al., 2015). Hence, this study used a quantitative formula constrained by time and score trends to accurately identify and capture momentum in basketball games. Then, we explored the relationship between momentum and basketball game outcomes and its role in different types of games. The formula used has been applied to study the short-term score difference variations between home and away teams (Chen and Fan, 2018). In this formula, $y(t)$ represents the point differential between the home team and away team at time t, s represents the increment of time, $y(s')$ represents the point differential between both teams at time s', and μ represents the threshold value for momentum:

$$M\left(s' \epsilon \left[t, s\right], \mu\right) := \frac{y(s') - y(t)}{s' - t} \geq \mu$$

2 Methods

2.1 Research sample

The research sample consists of all regular season games of the 2021–2022 CBA season. After excluding playoff and overtime games, there are 372 valid games. The full game event data are obtained from public data provided by Beitai Tech to the CBA official website.[1] This study used Python 3.0 (Python Software Foundation, version 3.0), a web scraping technology, to collect play-by-play event data for these 372 games and extract samples that met the criteria.

In the sports performance field, researchers have recognized the importance of three consecutive events for winning streaks and the hot hand effect (Carlson and Shu, 2007; Csapo et al., 2015). Therefore, this study posits that when setting the time constraints and score difference range for momentum, at least three complete offensive and defensive possessions should be included. In the 2021–2022 season of Chinese Basketball Association (CBA) games, the average duration of a complete offensive and defensive possession is about 32 s (data from CBA official website: https://www.cbaleague.com), and the average score per scoring possession is 2.1 points (data from Synergy: https://synergysports.com). Therefore, the minimum requirement for triggering momentum is achieving a net score difference of +6 points within 96 s. The net score is used because when discussing how momentum affects a game, one should not only consider a team's score, but also the differences in offensive and defensive performance between both teams (Burke et al., 2003). The net score can intuitively reflect the results of the competition between both teams over time. Additionally, to explore the impact of momentum on game outcomes reasonably based on the researchers' theory of "early success breeds later success," we believe that when cross-momentum occurs (for individual team evaluations), the appearance of the first momentum leads to subsequent changes in competitive momentum (Adler, 1981; Richardson et al., 1988; Iso-Ahola and Dotson, 2014). For example, in Figure 1, there are two lines, "Momentum A" and "Momentum B" (Both from the same team), which fit the definition of momentum. We selected the first-initiated "Momentum A" as our sample and deleted "Momentum B."

1 https://www.cbaleague.com

2.2 Reliability and validity of data

To determine the validity of the data from the CBA official website, four experienced basketball video analysts (all full-time video analysts for CBA teams) observed 20 randomly selected games, recording the game events and corresponding times for each game. Using the intraclass correlation coefficient to compare the recorded data with the CBA official website data, a high level of consistency was found (ICC = 0.97).

2.3 Statistical analysis

This study first conducted a descriptive analysis of the distribution of momentum in each quarter and the total number for the whole game, distinguishing between the winning and losing teams. Subsequently, a paired-sample Wilcoxon signed-rank test was used to determine if there were significant differences in the number of momentum occurrences between the two teams in each quarter. To observe the causes of momentum, the events of the first offensive and defensive possession when each momentum situation occurred were collected. A random forest was used to assess the importance of events to momentum strength. The significance level was set at $p < 0.05$.

To distinguish the game type, we first classified the 20 teams based on their winning rates (2021–2022 CBA regular season) using k-means clustering analysis (Sampaio et al., 2010a), with the elbow method was used to determine the optimal number of clusters. According to this analysis, team quality was automatically divided into three clusters, namely, the high winning rate teams as the Stronger Team, the medium winning rate teams as the Intermediate Team, and the low winning rate teams as the Weaker Team. Subsequently, the match between team quality and opponent team quality was used to determine the game type (Evenly Matched, Small Advantage/Disadvantage, Large Advantage/Disadvantage). In sports performance, distinguishing game type scenarios is a crucial step, as scenario variables can directly or indirectly affect the activities of teams and players (McGarry et al., 2013; O'Donoghue, 2014; Rein and Memmert, 2016; Gómez-Ruano, 2018). There are inherent differences in competitive strength due to differences in lineup strength and technical and tactical levels between the two teams in a basketball game. This difference is reflected not only in the game results but also in the game process. Hence, the game type scenario variable was controlled to distinguish the impact of these differences on the game.

The Kruskal–Wallis test was used to evaluate the differences in the number of momentum situations across five game types. Spearman's correlation coefficient was used to analyze the correlation between momentum and game outcomes in each quarter; the thresholds for weak, moderate, strong, and very strong correlations were defined as 0–0.3, 0.3–0.5, 0.5–0.7, and ≥0.7, respectively. Decision tree models have been widely applied in sports performance analysis (Young et al., 2020; Matulaitis and Bietkis, 2021; Serna et al., 2021; Jetzke and Winter, 2022). In this study, the CHAID decision tree classification model helped distinguish the role of momentum in different game types and quarters. To run the CHAID decision tree classification model, the game outcomes were used as the dependent variable, and the number and its difference values of momentum were used as independent variables. The training and validation sets accounted for 80 and 20% of the sample, respectively. The maximum depth of the model was set to five levels, and the model was validated using cross-validation.

Statistical analyses were performed using Python (Python Software Foundation, version 3.0) and IBM SPSS software (version 25.0; SPSS Inc., Chicago, IL, United States).

3 Results

3.1 Data identification results

In the 2021–2022 CBA regular season, 2,083 valid momentum samples were obtained (no crossover of momentum event sequences between the two teams was found). Each sample contained a complete event sequence from the start event to the end event. Additionally, for the completeness of the study, the quarter and time of each event were extracted.

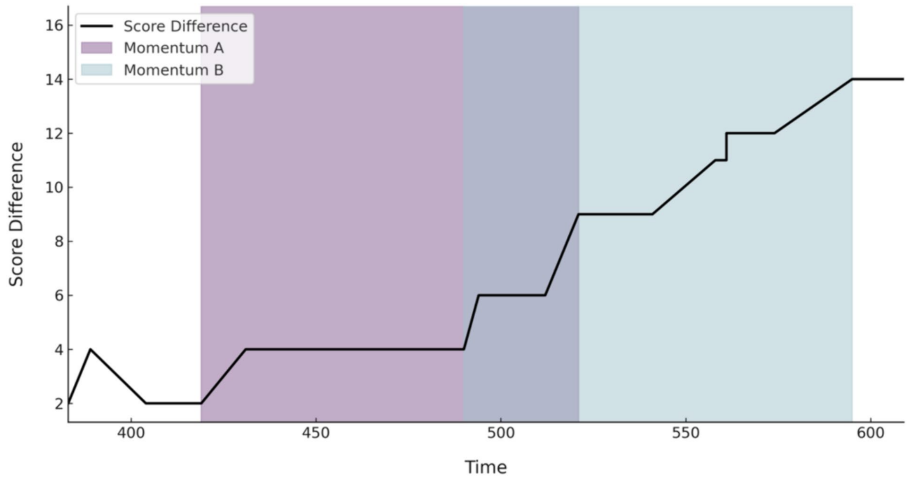

FIGURE 1
Cross momentum sketch map.

3.2 Statistical analysis results

Table 1 presents the descriptive statistics and paired-sample Wilcoxon signed-rank test results for the 2,083 samples from 372 games. The average number of momentum scenarios during the four quarters and overall momentum are both significantly higher for the winning team than for the losing team. From the first to the fourth quarter, the average momentum difference value between the winning and losing teams gradually decreased.

Table 2 presents the results of the random forest analysis. Free throw scouring has relatively high importance, followed by the opponent's two-point shots made and the opponent's turnovers.

Winning rate was used to determine team quality. Clustering analysis divided the 20 teams into three categories: Stronger Team (Cluster 2, $n = 6$, high winning rate = 75.0% ± 0.066), Medium Team (Cluster 1, $n = 8$, Intermediate winning rate = 54.9% ± 0.064), and Weaker Team (Cluster 0, $n = 6$, low winning rate = 18.4% ± 0.121). Furthermore, the match between a team's quality and the opponent's quality was used to determine different game types, namely (as shown in Table 3): Game Type 0 (Evenly Matched, $n = 113$), Game Type ±1 (Small advantage/Disadvantage, $n = 187$), and Game Type ±2 (Large advantage/Disadvantage, $n = 72$). For example, when the quality of the two competing teams is classified as Stronger Team and Weaker Team, the game type for the Stronger Team is +2 (large advantage), and for the Weaker Team is −2 (large disadvantage). This classification result groups similar game types together to explore the role of momentum in similar game situations.

The Kruskal–Wallis test was used to find the differences in momentum among the five game types across the four quarters. In the +1 and +2 game types, the differences in the number of momentum situations across the four quarters are consistently greater than 0. In other words, when facing weaker opponents, the likelihood of generating momentum is higher. Figure 2 shows the results of the Kruskal–Wallis test.

The number of momentum situations and their difference values in the four quarters were used as feature variables. Spearman's correlation coefficient was used to analyze the correlation between the features and the game outcomes. A correlation coefficient matrix was created and a heatmap was plotted (Figure 3). The correlation between the number and difference values of momentum in each quarter and the game outcome showed a decreasing trend, indicating that the momentum in the first quarter had the greatest impact on the game outcome.

Figure 4 shows the CHAID decision tree model. It uses game outcomes as the dependent variable, with the total sample divided into 80% training samples and 20% validation samples. The accuracy rates for the training and validation samples were 83.4 and 80.3%, respectively. The model contains 29 nodes, with the 5 game types as the root nodes. From the model results, it can be observed that in evenly matched situations, the total number of momentum situations can effectively aid in distinguishing between winning and losing samples. When the number of momentum situations is 4 or more, the win rate reaches 77.1%; when the number of momentum situations is 1 or 0, the win rate is only 16.2%. This indicates that striving for as many short-term scoring advantages as possible in the game positively impacts the game outcome. Additionally, there is no specific division of game quarters at this specific node level, indicating that in matches between equally matched teams, the number of momentum situations in different quarters has a minimal impact on the game. In contrast, when there is a certain quality gap between the two teams, momentum in the first quarter becomes an important factor in the "weaker beating stronger" scenario.

4 Discussion

Given the debate on momentum in previous research, we first aimed to present momentum in a quantifiable form to help establish an identifiable momentum conceptual framework based on relatively positive performance within specific time constraints and score change ranges. Then, using this conceptual framework, we accurately identified momentum in games and explored the role of this positive performance from the perspective of sports. The results of the difference test and correlation analysis showed that the momentum in the first quarter contributed the most to game outcome. After considering the impact of the game type scenario variables, the decision tree model further confirmed the importance of first-quarter momentum for weaker teams to defeat stronger teams. These findings provide a quantifiable method for identifying momentum, which aids sports performance scientists and psychologists in the further study of momentum, and helps coaches in formulating game strategies.

In matchups between evenly matched teams, offensive and defensive levels are relatively consistent, and the game is more likely to involve intense scoring battles, meaning frequent scoring exchanges between the two teams. This may be consistent with the changes in momentum between the two sides. In this situation, even if momentum is triggered several times (2–3 times), it may not affect the game outcome. Therefore, to gain an advantage in offensive and defensive levels and trigger more momentum, every detail in each quarter of the game becomes crucial, such as two-point shots and

TABLE 1 Descriptive statistics and paired-sample Wilcoxon signed-rank test results.

	Sum		Mean ± *SD*		Difference value (W-L)		Paired-sample Wilcoxon Signed-Rank Test	
	W	*L*	*W*	*L*	Mean	*SD*	*p*-value	*Z*
Q1	360	160	0.97 ± 0.85	0.43 ± 0.58	0.54	0.27	<0.001	−8.605
Q2	351	170	0.95 ± 0.82	0.46 ± 0.65	0.49	0.17	<0.001	−7.973
Q3	349	176	0.94 ± 0.86	0.47 ± 0.65	0.47	0.21	<0.001	−7.302
Q4	313	204	0.84 ± 0.85	0.55 ± 0.69	0.29	0.16	<0.001	−4.624
Total	1,373	710	3.69 ± 1.65	1.91 ± 1.18	1.78	0.47	<0.001	−13.108

defensive rebounds (Lorenzo et al., 2010), assists (García et al., 2013), shooting percentage, and steals (Çene, 2018). In this context, momentum accumulation in a single quarter seems less important, and analyzing the impact of momentum on the game outcome by considering only one quarter is less effective than evaluating the overall value of momentum throughout the game.

The impact of momentum shows a changing trend at different stages of the game. Although the final stages of the game are considered very crucial (Bar-Eli and Tractinsky, 2000), especially the fourth quarter where every detail can affect the outcome (Ferreira et al., 2014), the influence of momentum on the game outcome decreases quarter by quarter. This observation has rarely been mentioned in previous studies. We acknowledge the unique characteristics of the first quarter of a basketball game because players, influenced by pre-game excitement, often exhibit higher motivation and better physical condition (Ben Abdelkrim et al., 2010), which usually reflects the true capabilities of the team (Martínez, 2014). The logic behind this unique characteristic may be related to the "success breeds success" theory reported by sports psychologists. Early success has been confirmed to influence the subsequent psychological state in sports competitions (Adler, 1981; Richardson et al., 1988; Iso-Ahola and Dotson, 2014; Morgulev, 2023). The importance of first-quarter momentum to the game outcome also supports this view from the perspective of sports performance analysis. The concept of momentum involves the psychological and emotional aspects of the game, reflecting the confidence and morale of the team and players, which are attributes difficult to quantify in the traditional definition of momentum.

TABLE 2 Random forest analysis results.

Feature	Importance
Free throw scoring	30.89%
Opponent's two-point shots made	14.91%
Opponent's turnovers	7.79%
Missed field goals	4.01%
Fouls on opponent's shots	3.62%
Opponent's three-point shots made	3.20%
Defensive rebounds	2.49%
Missed free throws	2.30%
Technical foul free throws	2.27%

Momentum has been a research topic in sports for over 40 years. It has always been considered a difficult concept to verify scientifically (Burke and Houseworth, 1995; Burke et al., 1997, 2003), but with the enrichment of statistical analysis methods and the exploration of contextual factors, researchers have been able to detect the existence of momentum through more objective and scientific empirical analysis (Hughes et al., 2006; Markman and Guenther, 2007; Dumangane et al., 2009; Morgulev et al., 2020; Gibbs et al., 2022; Weimer et al., 2023). Most of these empirical analyses are based on the dependence and non-stationarity of sequences. Sequence dependence refers to the idea that one event depends on adjacent events, while non-stationarity refers to the idea that the changes in success rate over the ongoing game exceed the possibility of being explained by chance (Moesch et al., 2014). Overall, both theoretical research and empirical analysis on momentum strongly emphasize the possibility that momentum may have a continuous structure (Iso-Ahola and Dotson, 2014, 2016). Clearly, sequences of micro-level events support the formation of momentum, and the value of these sequences lies in their representation of specific continuous events and behaviors in games, revealing the dynamic process of the game. Based on this viewpoint, establishing a momentum framework and then studying whether there are changes in the resulting sports performance, behavior, or psychology may aid in better understanding the momentum phenomenon, thereby making greater progress in theoretical research and practical applications.

The momentum framework in this study reflects the differences in offensive and defensive performance between two teams in a short period, testing the players' continuous scoring ability and defensive quality. This is what differentiates the momentum framework defined in this study from the hot hand effect. Emphasizing the importance of defense in momentum is inspired by the study of Burke and Burke (1999) and Burke et al. (2003). We also attempted to use linear regression and Lasso models to determine the impact of defensive metrics on momentum. Although the model results showed that the opponent's shooting scores had a significant negative impact on momentum and the opponent's turnovers had a significant positive impact. However, the explanatory power of the models was low, so we could not rigorously confirm the specific impact of these metrics. This may be due to the sample size limitations or reflect the limitations of such models in studying momentum impact metrics. This aspect needs to be improved and refined in future research.

TABLE 3 Classification of game type and situation based on quality of the competing teams.

Team quality (cluster)	Winning rate (Mean ± *SD*)	Opponent team quality	Game type	Game situation
Stronger team (cluster 2)	75.0% ± 0.066	Stronger team	0	Evenly matched
		Intermediate team	+1	Small advantage
		Weaker team	+2	Large advantage
Intermediate team (cluster 1)	54.9% ± 0.064	Stronger team	−1	Small disadvantage
		Intermediate team	0	Evenly matched
		Weaker team	+1	Small advantage
Weaker Team (cluster 0)	18.4% ± 0.121	Stronger team	−2	Large disadvantage
		Intermediate team	−1	Small disadvantage
		Weaker team	0	Evenly matched

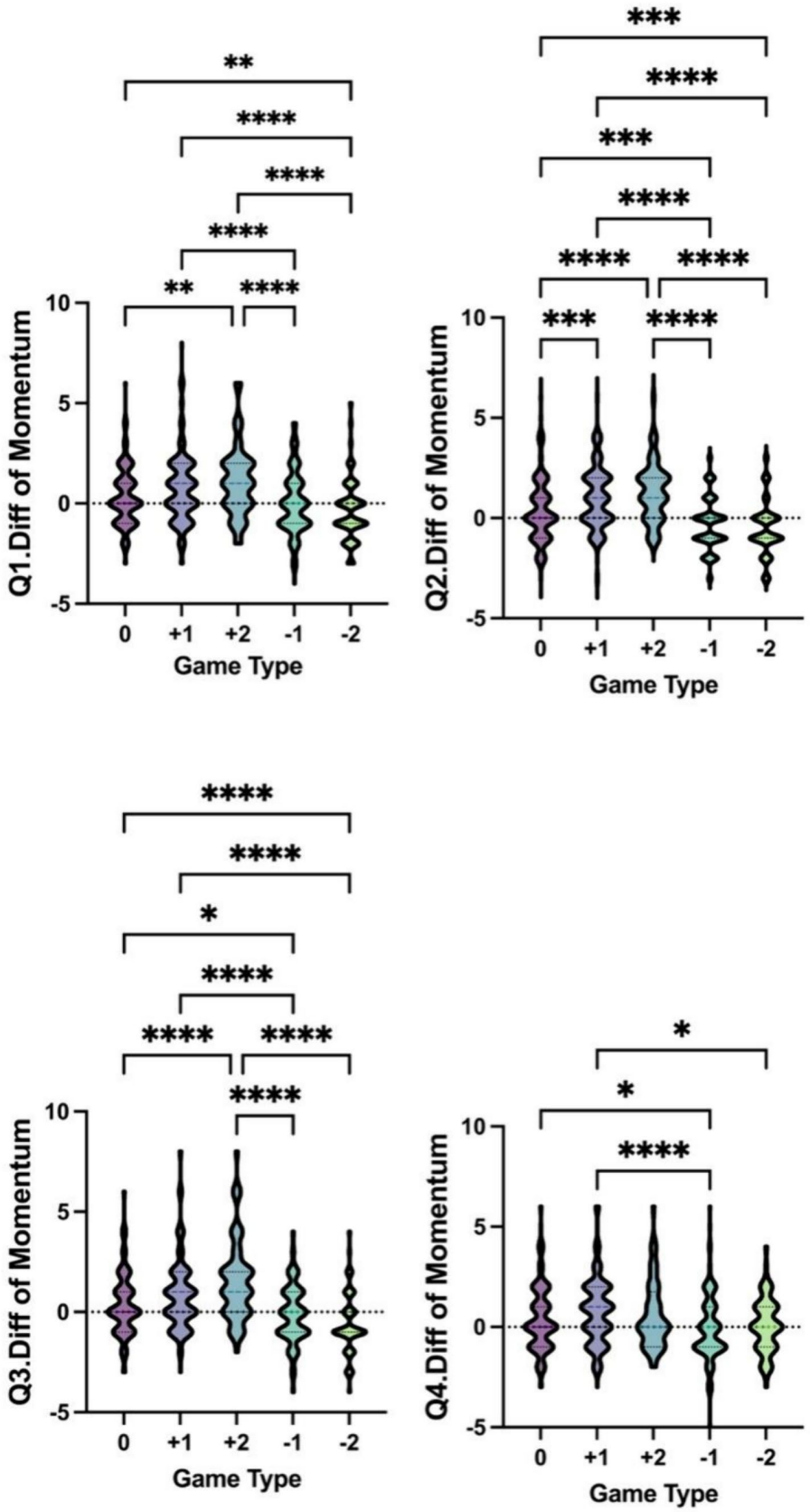

FIGURE 2
Kruskal–Wallis test results for differences in momentum among the five game types across the four quarters. In this figure, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ****$p < 0.0001$.

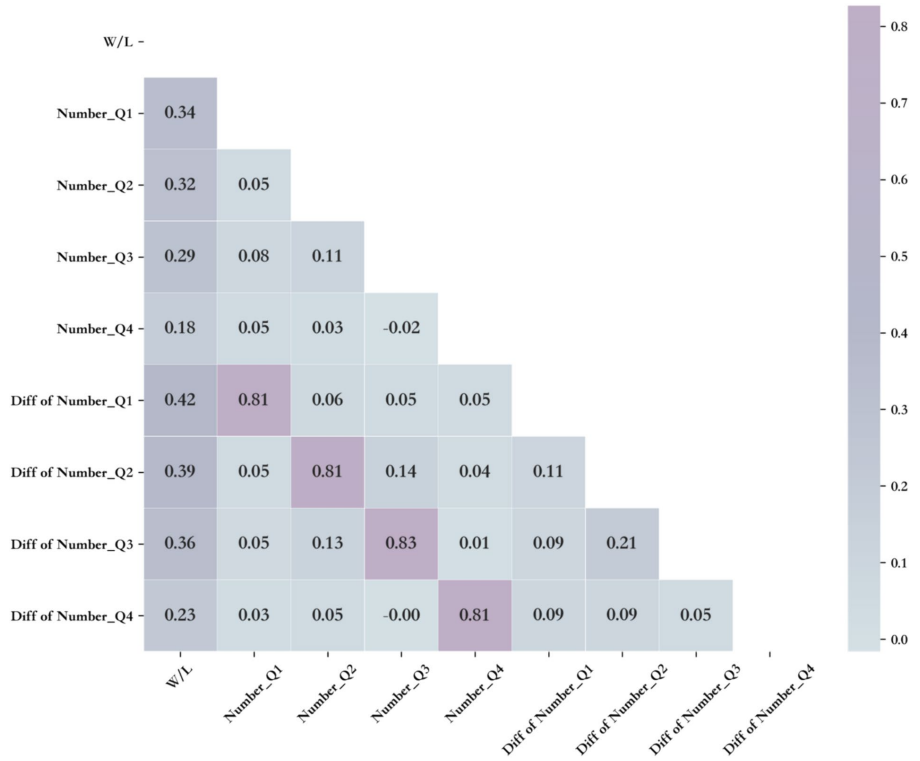

FIGURE 3
Spearman's correlation analysis results.

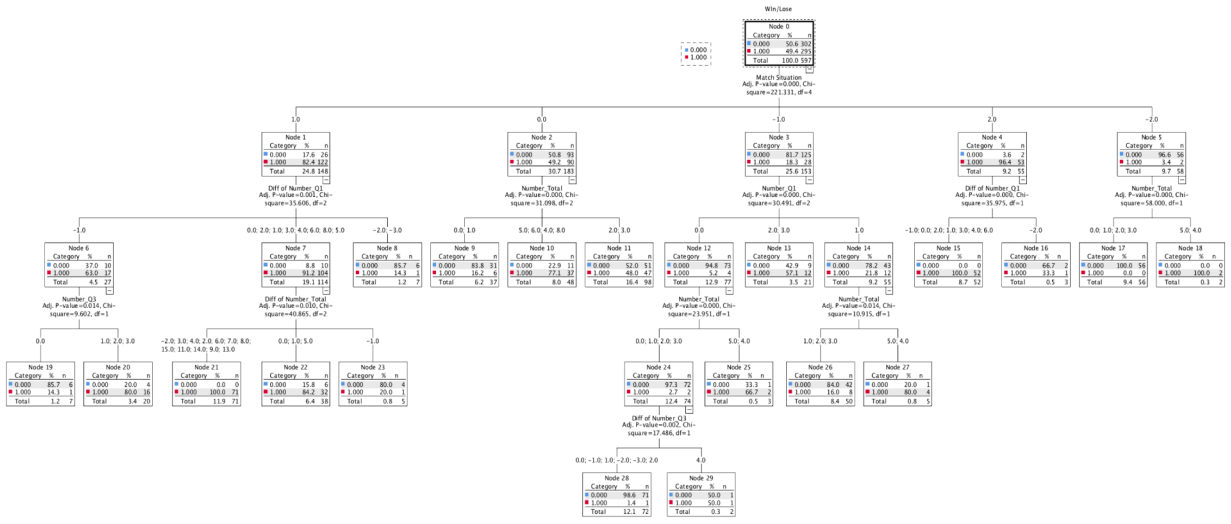

FIGURE 4
Results of the CHAID decision tree model with the outcome of the game as the independent variable.

5 Conclusion

This study presents momentum in a quantifiable form, which aids in establishing an identifiable momentum conceptual framework. Momentum is specifically defined as the relatively positive performance of the team in offense and defense within a specific period. Through this framework, momentum can be defined more accurately in games, and its impact on game outcomes can be further explored. The results show that the momentum in the first quarter contributes the most to the game outcome, especially when weaker teams defeat stronger teams. It also emphasizes that the influence of momentum decreases quarter by quarter in different stages of the game.

Overall, this study provides a different perspective for the scientific validation of momentum. Momentum is not just a subjective

concept; through quantification methods, its role in the game can be objectively assessed. This provides a reference for coaches in formulating game strategies and also offers new research methods on sports performance for scientists and psychologists. Future research can further explore the influence of different contextual factors on momentum.

6 Limitations and future research

It should be acknowledged that there are some limitations in this study. Firstly, we were unable to conduct an in-depth study of the event sequences within the momentum, which could help in understanding the causes and cessation of momentum. Secondly, we did not examine the impact of timeouts on momentum, which could be very helpful for formulating game strategies. Furthermore, we lack a deeper study of cross momentum, which could help identify key factors in sustaining momentum. Finally, due to the small sample size and insufficient dimensions, we were unable to apply linear regression or Lasso models in this study. These models could help explore the impact of game events on momentum-related dependent variables, such as the duration of momentum.

With a sufficient sample size, the events within the momentum can be included in the analysis to explore the role of different events in generating and stopping momentum. With a sufficient sample size, future research can focus on the complete event sequences within the momentum, analyzing the impact of single events or combinations of events on momentum, and can also compare events outside of momentum to further understand how to create momentum in a game. Furthermore, in-depth studies on the performance of momentum in different sports and how to apply this quantification method to other fields can be conducted.

Data availability statement

The datasets presented in this article are not readily available because the data that support the findings of this study are available from the corresponding author, MZ, upon reasonable request. Requests to access the datasets should be directed to zhangmingxin@sus.edu.cn.

Author contributions

MQ: Conceptualization, Investigation, Validation, Visualization, Writing – original draft. SZ: Methodology, Software, Writing – review & editing. QY: Data curation, Writing – review & editing. CZ: Formal analysis, Writing – review & editing. MZ: Conceptualization, Funding acquisition, Project administration, Resources, Writing – review & editing.

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Conflict of interest

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

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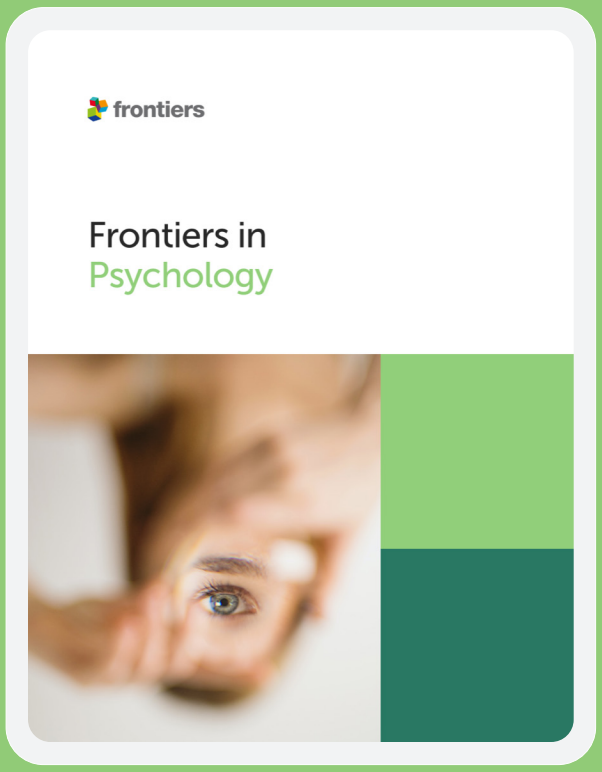

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