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ORIGINAL ARTICLE

Relationship between leg muscle explosive power and sickle kick speed in pencak silat athletes

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim: Pencak silat is a traditional martial art originating from Indonesia, characterized by dynamic movements and complex techniques. Practitioners are required to possess a high level of physical fitness, including strength, speed, and precision, particularly during attack and defense actions. One of its essential techniques is the sickle kick, which demands both leg muscle explosiveness and execution speed. This study aimed to examine the relationship between leg muscle explosive power and sickle kick speed.

Material and Methods: This study used a descriptive method with a correlational design and a quantitative approach. The sampling technique was total sampling, involving 42 pencak silat athletes. The research instruments included a vertical jump test to assess leg muscle explosive power and a sickle kick speed test, which involved performing kicks toward a kicking box for 1 minute (30 seconds with the left leg and 30 seconds with the right). Data were analyzed using normality, linearity, and correlation tests with the assistance of SPSS version 21.

Results: The results showed that the significance value for the relationship between leg muscle explosive power and sickle kick speed was 0.01 < 0.05, indicating a statistically significant relationship.

Conclusions: There is a significant relationship between leg muscle explosive power and sickle kick speed in pencak silat athletes. These findings can serve as a reference for identifying physical factors that contribute to improving kick speed in pencak silat athletes.

Keywords: pencak silat, leg muscle explosive power, sickle kick speed, vertical jump, martial arts performance

Introduction

Pencak silat, as a traditional Indonesian martial art, encompasses a wide range of dynamic techniques that combine elements of self-defense, discipline, and athleticism. Effective performance in this sport depends not only on technical mastery but also on the athlete's physical attributes, particularly strength, speed, and coordination. Among the core techniques, the sickle kick stands out due to its complexity and reliance on explosive leg power to achieve both speed and accuracy. Understanding the physical components that contribute to the effectiveness of this movement is essential for improving athletic performance in pencak silat.

Sport consists of a series of physical activities performed in a structured and systematic manner to improve an individual's functional abilities, both individually and in groups [1, 2]. One of the traditional sports of Indonesia is pencak silat [3]. This martial art represents an important part of the country's cultural heritage, embodying traditional values and practices passed down from generation to generation [4, 5].

This form of pencak silat serves not only as a means of self-defense but also as a way to connect individuals with the cultural roots and identity of the Indonesian nation [6]. The complex movements and techniques of pencak silat engage the entire body, combining a harmonious blend of physical strength, mental agility, and spiritual awareness [7]. As a martial art, pencak silat is characterized by the use of all body parts and limbs as tools for self-defense. Techniques can be performed either bare-handed or with weapons [4]. The movements in pencak silat are purposeful, controlled, directed, and coordinated [8]. They encompass four main interconnected aspects: mental-spiritual, self-defense, sport, and art.

Syaifullah and Lingsir Maghribi [9] explain that an attack in pencak silat is a self-defense action involving the use of the arms or legs to strike a specific target on the opponent's body. During a match, an athlete must demonstrate proper stance, balanced footwork, and a variety of attack and evasion techniques before returning to the original position [10]. Standard attack techniques in pencak silat include kicks, punches, falls, and sweeps. Among these, kicks are used more frequently in competition because they are awarded higher scores than punches. A punch is worth 1 point, while a kick is worth 2 points. If an athlete successfully avoids an opponent's attack while delivering a kick that hits a valid target, the athlete receives a score of 1+2 [11].

The results of a study by Saphie et al. [12] indicate that pencak silat athletes who deliver a greater number of kicks demonstrate not only

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aggressiveness in competition but also strategic superiority and technical mastery. Kicks often yield higher points than punches when they accurately hit the opponent [13]. In pencak silat, various types of kicks are used, including straight, crescent, side, and back kicks [14]. The sickle kick is one such technique and is commonly employed during matches as an offensive move [15]. To be effective, kicks must be fast and accurately targeted so that the opponent cannot easily anticipate the attack [16]. Consistent and precise kicking increases the opportunity to score, thereby allowing the athlete to dominate the match [17].

In the context of Pencak Silat, general physical attributes such as muscular strength, speed, and coordination must be effectively transferred into specific technical movements. Kicking techniques, in particular, require the rapid transformation of muscular force into high-velocity motion. Understanding how foundational physical qualities like lower-limb explosive power directly influence the speed and precision of kicks is essential for optimizing athletic performance.

The execution of a sickle kick relies on several key components that contribute to the effectiveness of the movement. One of the primary components is the explosive power of the leg muscles [18, 19]. This refers to the ability of the leg muscles to generate force rapidly, which is essential for producing high-speed and powerful kicks. In pencak silat, greater leg muscle explosive power enables faster and stronger kicks, increasing the likelihood of delivering an effective attack against the opponent [5, 20].

Analysis of previous research findings has shown that the effectiveness of kicks in pencak silat is closely linked to technical execution, physical conditioning, and in particular, the explosive power of the legs. Researchers emphasize that explosive leg strength plays a decisive role in achieving optimal speed and accuracy during offensive movements, especially sickle kicks. Given the complexity and competitive importance of this technique, understanding the physical factors that influence its performance remains a relevant area of exploration. In this context, examining the connection between leg muscle explosive power and sickle kick performance offers valuable insights for both training and competition.

It is assumed that athletes with greater explosive leg power are able to perform sickle kicks with higher speed and precision, which may contribute to better scoring outcomes during competition. This assumption aligns with the idea that muscular explosiveness enhances both the mechanical efficiency and tactical effectiveness of kicking techniques. Therefore, this study aims to examine the relationship between leg muscle explosive power and sickle kick speed in pencak silat athletes.

Materials and Methods

Participants

The population in this study consisted of all 42 martial artists from the Melati Sakti School in Pekalongan City. A total sampling technique was applied, meaning that all members of the population were included as research participants.

The sample included 27 male and 15 female athletes, aged between 16 and 22 years (mean age: 18.5 ± 1.8 years). Their training experience ranged from 2 to 6 years. All participants were actively involved in regular pencak silat training at the time of the study.

A formal power analysis was not conducted due to the total sampling method; however, the inclusion of all 42 available athletes was considered sufficient for detecting moderate correlations ($r \geqslant 0.5$) with a power of 0.80 and alpha of 0.05, based on standard guidelines.

This study was conducted in accordance with the ethical standards of the institutional research committee and the principles of the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Semarang State University. All participants were informed about the purpose and procedures of the study, and written informed consent was obtained prior to data collection.

Research Design

The study employed a quantitative method with a cross-sectional design. The explosive power of the lower limbs was assessed using the vertical jump test performed on the Just Jump System (Probotics, USA), a portable contact mat that estimates jump height based on flight time. This method is widely used in field settings due to its practicality and strong test-retest reliability [21]. However, validation studies have shown that the Just Jump System systematically overestimates jump height compared to force platforms. To improve measurement accuracy, a correction equation proposed by McMahon et al. [22] was applied:

$$H_{corrected} = 0.825 \cdot H_{JJ} + 1.7$$

Where: H_{JJ} – the jump height (in centimeters) as measured by the Just Jump System; 0.825 and 1.7 – empirically derived coefficients based on comparison with gold-standard force platform measurements.

Participants were instructed to maintain a consistent body posture during take-off and landing to minimize measurement error. The protocol followed standard procedures for assessing explosive power in martial artists [21]. Additionally, the device was calibrated before each session, and jump trials were repeated if execution did not meet posture consistency standards.

The speed of the sickle kick was assessed using the Pecing Box kick test, as described in traditional

Pencak Silat practice [22]. The test consisted of a 1-minute trial, divided into two 30-second sessions: one for the left leg and one for the right leg. Participants performed continuous crescent (sickle) kicks against a padded target (Pecing Box), and the total number of accurately executed kicks within each time interval was recorded. This number served as the performance indicator for kick speed. Similar test formats have been applied in previous research on Pencak Silat athletes to evaluate kicking performance under time constraints [23, 24].

The padded Pecing Box target was positioned at a standardized height of 1 meter from the ground. Kicks were considered valid if they made clean contact with the target without loss of balance or form. Observers were trained to record only clearly executed kicks, and ambiguous movements were excluded. The assessment was performed by two independent observers. Inter-rater reliability was established prior to testing (Cohen's kappa = 0.91), ensuring consistency in kick evaluation.

All tests were conducted indoors on a non-slip rubber surface in the training hall of the club. The temperature was maintained between 24–26°C, and assessments were carried out between 08:00 and 11:00 a.m. to ensure consistency and minimize circadian variation in physical performance.

Statistical Analysis

The statistical analysis included several steps. First, descriptive statistics were calculated to summarize the participants' physical performance scores, including means and standard deviations for both leg muscle explosive power and sickle kick speed. The normality of data distribution was assessed using the Kolmogorov–Smirnov test to determine the suitability of parametric tests. To verify whether the relationship between variables met the assumption of linearity, a deviation from linearity test was conducted. Following the assumption checks, Pearson product-moment correlation analysis was used to examine the relationship between leg muscle explosive power and the speed of the sickle kick. All statistical procedures were performed using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA). A significance level of $p < 0.05$ was adopted for all tests.

Results

Descriptive statistics were calculated for the two main variables: the explosive power of the leg muscles and the speed of the sickle kick. Table 1 presents the minimum, maximum, mean, and standard deviation values for each variable measured in the sample of 42 Pencak Silat athletes.

Based on the data in Table 1, the athletes demonstrated moderate variation in both physical performance measures. The average vertical jump height was 53.77 cm, with a standard deviation of 8.44 cm, indicating variability in lower-limb explosive strength. The average sickle kick speed was 19.58 kicks per minute, with a standard deviation of 3.62, reflecting differing levels of kicking efficiency across participants.

A normality test was conducted using the Kolmogorov–Smirnov method to determine whether the data for each variable followed a normal distribution. The results are presented in Table 2.

As shown in Table 2, the significance value for explosive power of the leg muscles was 0.463, and for sickle kick speed it was 0.070. Since both values are greater than the threshold of 0.05, the null hypothesis of normality cannot be rejected. Therefore, both variables are considered to be normally distributed.

To determine whether a linear relationship exists between the two variables, a linearity test was conducted. The results are shown in Table 3.

As shown in Table 3, the significance value for the Deviation from Linearity is 0.101, which exceeds the threshold of 0.05. This indicates that the relationship between leg muscle explosive power and sickle kick speed does not significantly deviate from linearity. Therefore, it is appropriate to proceed with parametric correlation analysis.

Table 1. Descriptive Statistics for Explosive Leg Power and Sickle Kick Speed

Variable	Minimum	Maximum	Mean	Standard Deviation
Explosive power of leg muscles (cm)	33	70	53.77	8.44
Sickle kick speed (kicks/min)	14	27	19.58	3.62

Note: Explosive leg power was measured using the vertical jump test on the Just Jump System, with jump height recorded in centimeters. Sickle kick speed was measured as the total number of correctly executed kicks performed within one minute, divided equally between the left and right legs.

Table 2. Kolmogorov–Smirnov Test of Normality

Variable	Statistic	df	Sig.	Interpretation
Explosive power of leg muscles	0.975	42	0.463	Normally distributed
Sickle kick speed	0.951	42	0.070	Normally distributed

Note: The threshold for normality was set at $p > 0.05$.

Table 3. Linearity Test: Deviation from Linearity

Variables	Mean Square	F	Sig.	Interpretation
Explosive power of leg muscles × Sickle kick speed	103.313	1.778	0.101	Linear relationship confirmed

Note: A significance value (p) greater than 0.05 in the Deviation from Linearity test indicates a linear relationship.

Table 4. Pearson Correlation Between Explosive Leg Power and Sickle Kick Speed

Variable	1. Explosive Power (cm)	2. Sickle Kick Speed (kicks/min)
1. Explosive Power	1.000	0.513*
2. Sickle Kick Speed	0.513*	1.000
Sig. (2-tailed)	–	0.001
N	42	42

Note: * = Correlation is significant at the 0.05 level (2-tailed).

A Pearson correlation analysis was conducted to examine the strength and direction of the relationship between leg muscle explosive power and sickle kick speed. The results are presented in Table 4.

The results in Table 4 show a statistically significant positive correlation between leg muscle explosive power and sickle kick speed ($r = 0.513$, $p = 0.001$). Since the p-value is below the 0.05 threshold, the relationship is considered significant. The correlation coefficient of 0.513 indicates a moderate positive relationship, suggesting that higher explosive leg power is associated with greater sickle kick speed in Pencak Silat athletes.

According to Cohen's criteria, this corresponds to a moderate effect size. The 95% confidence interval for the correlation ranged from 0.22 to 0.72, confirming the reliability of the observed association.

Discussion

This study aimed to examine the relationship between leg muscle explosive power and sickle kick speed. The results revealed a statistically significant moderate positive correlation between these two variables ($r = 0.513$, $p = 0.001$). Athletes with greater leg muscle explosiveness demonstrated a higher number of effective kicks within the one-minute test, indicating that explosive strength plays a meaningful role in kick performance.

Good physical condition enhances overall fitness and improves the functional capacity of the body's systems, thereby enabling athletes to achieve better performance outcomes [26, 27]. The main components of physical condition include stamina, strength, muscular endurance, and speed – all of which are essential for supporting pencak silat training and competition [28, 29]. To perform optimally, an athlete must maintain a high level of physical fitness [30]. In sports, explosive power is a key biomotor ability, as it determines how forcefully an athlete can strike, kick, sprint, or push off during performance [31, 32, 33, 34]. Explosive power is considered a fundamental component of physical condition required in nearly all sports, including pencak silat [35].

The results of this study indicate a significant positive relationship between leg muscle explosive power and the speed of the sickle kick. Athletes with higher explosive strength in their leg muscles demonstrated a greater ability to perform fast and powerful sickle kicks. These findings are consistent with the results of Jamal et al. [17], who reported that explosive muscle power significantly influences the speed of the front kick in pencak silat, with a contribution of 13.6%. This is further supported by Zaqi Arief Firmanto et al. [36], who found a significant relationship between leg muscle strength and kick speed in silat athletes. While the findings of this study are consistent with previous research by Jamal et al. [17] and Zaqi Arief Firmanto et al. [36], a critical comparison reveals some important distinctions. For instance, while Jamal et al. focused on front kicks in adolescent athletes and reported a lower contribution (13.6%), the current study investigated sickle kicks in a mixed-gender population and found a moderate correlation ($r = 0.513$). This suggests that the contribution of explosive leg power may vary depending on the kick type and technical complexity. Additionally, while Doewes et al. [37] emphasized the biomechanical basis of lower-limb strength in rotational acceleration, our findings provide empirical confirmation of this principle in a real athlete sample, reinforcing its relevance for training applications.

Biomechanically, kicking in pencak silat highlights the critical role of lower limb strength in generating optimal acceleration, especially during kicking techniques. This strength affects the production of torque, rotational kinetic energy,

and ultimately determines both the speed and accuracy of the kick. Executing an effective kick requires explosive contraction of the leg muscles, particularly the quadriceps, hamstrings, and gluteal muscles. The movement starts with a powerful push from the supporting leg, followed by a free leg swing that generates high rotational momentum [37].

The explosive power of an athlete's muscles reflects the overall quality of their performance. Athletes with insufficient leg strength are often more predictable, making it easier for opponents to anticipate and counter their kicks [38]. Explosive strength in the leg muscles, particularly in the feet and lower limbs, is a key factor in enabling athletes to compete at a high level [39]. This type of muscular power plays a crucial role in generating an effective sickle kick. When the explosive power of the leg muscles is at an optimal level, the execution of the sickle kick tends to be more effective in terms of strength, speed, and accuracy [40].

However, many silat athletes continue to exhibit below-average performance in executing the sickle kick. This suggests deficiencies in both technical execution and physical conditioning that support the movement, highlighting the need for targeted and specific training programs to enhance its effectiveness and efficiency. Several factors can influence the quality of a sickle kick, including distance to the target, balance of the supporting leg, body positioning, kick trajectory, and pelvic rotation [41, 42, 43]. Proper foot positioning must be consistently trained to develop automatic and efficient movement patterns for power application. The success of the kick largely depends on reaction speed, response time, and execution accuracy [44].

The training process is a crucial factor in enhancing athletic performance [45]. Regular training, particularly targeting the leg muscles, is essential for developing strong and technically sound kicking skills [46, 47]. Powerful, fast, and accurate kicks require specialized training programs that focus on leg strength, leg length, muscular endurance, and the application of effective training methods [48]. Speed-oriented training, ballistic exercises, and plyometrics have been shown to improve kick performance that demands high power output [45]. Based on the findings of this study, there is a significant relationship between leg muscle explosive power and the speed of the sickle kick. The greater the explosive power, the higher the kick speed and effectiveness. These results suggest that optimizing explosive leg strength through structured and specific programs such as plyometric and speed training is essential for improving sickle kick performance in athletes.

The results of this study have practical implications for coach education and the design of training curricula in martial arts disciplines. Specifically, the findings support the inclusion of targeted plyometric and speed-strength exercises in skill development programs to enhance kicking performance. For physical education and coaching curricula, this highlights the importance of integrating biomechanical principles and evidence-based training protocols to improve specific techniques such as the sickle kick. Martial arts instructors could incorporate performance diagnostics, such as jump tests, into regular assessments to monitor explosive strength development in student-athletes.

This study confirms a significant and meaningful relationship between leg muscle explosive power and sickle kick speed in pencak silat athletes. The findings emphasize the critical role of lower-limb strength in executing fast and effective kicks, highlighting the biomechanical and practical importance of explosive muscle performance. These results support the integration of specific strength and speed training protocols in pencak silat practice to enhance kick execution and competitive success.

Although the study does not present a new pedagogical model, it reinforces the relevance of integrating physical testing and conditioning into sport-specific skill development. The findings can inform coaching practice by linking a measurable physical quality (explosive leg strength) to technical performance. Embedding such evidence-based approaches into training programs and coach education can strengthen the alignment between sports science and martial arts pedagogy.

Limitations and Future Research

This study has several limitations. It was conducted on a specific group of athletes within a limited age and experience range, which may affect the generalizability of the findings to other populations or levels of competition. Additionally, only two performance variables were analyzed, without considering other potentially influential factors such as coordination, flexibility, or psychological readiness. Future research should explore these additional components and examine the long-term effects of targeted training interventions on sickle kick performance across broader athlete populations.

Although the study confirms the importance of leg muscle explosiveness in kicking performance, it does not introduce an intervention, comparative protocol, or theoretical advancement. The correlational design provides validation of existing findings within a new athlete sample, but lacks experimental manipulation, such as comparing different training methods (e.g., plyometric vs. traditional). Future research could enhance novelty by exploring how specific training interventions influence biomechanical outcomes, or by comparing elite and novice athlete populations. Investigating interactions between multiple physical and

cognitive variables would also extend the theoretical contributions of such studies.

Conclusions

There is a significant relationship between leg muscle explosive power and the speed of the sickle kick in pencak silat athletes. The results of this study can serve as a reference for designing training programs and as a benchmark for developing each athlete's potential to achieve success at various levels of competition. These findings have important implications for pencak silat training. Coaches and athletes are encouraged to focus on improving explosive leg strength through consistent and progressive training. The application of specific speed- and strength-based training methods is believed to enhance the effectiveness of the sickle kick from both technical and physical perspectives.

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Conflict of Interest

The authors declare no conflict of interest.

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ORIGINAL ARTICLE

The effectiveness of traditional games in improving emotional intelligence in children aged 3–6 years: a literature review

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Abstract

Background and Study Aim: Early childhood is a critical period for the development of emotional intelligence, which influences a child's future ability to build relationships and adapt socially. Rapid technological changes and reduced opportunities for direct social interaction have affected how children experience emotional growth. This study aims to examine the effectiveness of traditional games in improving emotional intelligence in children aged 3 to 6 years through a literature review approach.

Material and Methods: A systematic literature review was conducted according to PRISMA guidelines. Articles were collected from multiple academic databases, including Google Scholar, Scopus, ResearchGate, SINTA, and Garuda. The search used keywords in Indonesian and English, such as "traditional games", "emotional intelligence", and "early childhood". The inclusion criteria were: (1) studies published between 2014 and 2024, (2) full-text peer-reviewed articles, (3) participants aged 3 to 6 years, and (4) clear focus on emotional intelligence and traditional play. Eight eligible studies were analyzed qualitatively. The analysis focused on emotional indicators such as empathy, self-control, and cooperation.

Results: The reviewed studies demonstrated that traditional games contribute to both general emotional development and measurable improvements in emotional intelligence. Specifically, 6 out of 8 studies reported enhancements in empathy, self-regulation, and cooperative behavior. For instance, one intervention study reported a 76% improvement in emotional intelligence scores. Traditional games such as congklak, Balogo, and Cublak-cublak Suweng served not only as entertainment but also as structured learning tools that foster interpersonal engagement and emotional growth.

Conclusions: The reviewed studies confirm that traditional games can effectively support emotional intelligence in early childhood. These games should be considered for integration into early childhood education programs. Their use may enhance emotional awareness, strengthen peer relationships, and support collaborative behavior among children.

Keywords: traditional games, emotional intelligence, early childhood, emotional development, cooperative play

Introduction

In early childhood, the foundations of emotional, social, and behavioral development are formed through direct interaction with the surrounding environment. As children grow, their ability to recognize, express, and manage emotions plays a central role in shaping interpersonal relationships, learning readiness, and long-term psychological well-being. Emotional development in this period is influenced by multiple factors, including family dynamics, cultural practices, and the types of play experiences available to the child.

Sport can be understood as a form of physical training aimed at preparing the body to function more effectively, maturely, and efficiently [1, 2]. In the educational context, sport plays a critical role in building character, promoting physical health, and supporting psychosocial development, particularly among children and adolescents. Participation in physical activities contributes to the growth of life skills such as resilience, intrinsic motivation, and self-efficacy, which are central components of youth development programs [3, 4, 5, 6].

Despite having more discretionary time for physical activity, many children today face restricted access to safe sports facilities and healthy recreational spaces. This limits their opportunities for physical and emotional growth [7, 8]. Moreover, conventional physical education programs do not always respond adequately to students' emotional needs. This shortfall is further worsened by the rise in children's dependence on digital devices. As a result, the quality of face-to-face interaction has decreased. Research has shown that frequent technological interference in parent–child interaction, particularly involving mobile phones, can disrupt emotional regulation and contribute to behavioral difficulties in young children [9, 10]. This

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disruption may reduce opportunities for emotional learning through direct social engagement.

Emotional intelligence has emerged as a core aspect of a child's holistic development [11]. It involves recognizing, understanding, and managing one's own emotions, as well as responding appropriately to others. This includes skills like empathy, communication, and cooperation. According to several studies, emotional intelligence supports mental and physical well-being, contributes to non-aggressive behavior, and correlates positively with academic success and the quality of social relationships [11, 12]. However, the rapid pace of technological and social change has contributed to the erosion of children's emotional interactions. Many now lack opportunities for authentic and meaningful social engagement.

Traditional games represent one natural and culturally relevant method to improve emotional intelligence. These games encourage teamwork, empathy, and face-to-face communication, all of which are critical for social-emotional growth [13]. In contrast to digital games, which tend to isolate children and limit interaction, traditional games require physical involvement and adherence to shared rules. Children learn to express emotions such as joy, frustration, and disappointment in a social setting that feels safe and familiar. These interactions nurture social skills such as cooperation and self-regulation [8].

Several studies have examined how traditional games support emotional development. For instance, children engaged in regular traditional play have demonstrated enhanced emotional regulation and empathy [14], while culturally specific games like engklek, gobak sodor, and petak umpet have been associated with improved conflict resolution and social cooperation skills in Indonesian contexts [15]. Together, these findings suggest a consistent role of traditional games in nurturing emotional competencies across settings.

The reduced presence of traditional games in school curricula further contributes to their marginalization. Children's preferences are increasingly shaped by global digital trends. While digital games offer certain cognitive benefits, they rarely provide the kind of emotional and social stimulation found in traditional play [16]. Research has shown that children who engage in traditional games use the internet less and demonstrate better social adjustment [17].

Analysis of research findings has shown that traditional games contribute to the development of emotional regulation, empathy, and cooperation among children. Researchers emphasize that these games foster interaction in socially meaningful contexts, supporting emotional learning through structured play. However, findings from these studies remain fragmented, and systematic integration of the results is lacking. This limits their usefulness for educators and policymakers seeking evidence-based interventions. Within the context of physical culture pedagogy, traditional games represent a form of structured physical activity that simultaneously engages emotional, social, and motor domains. Their incorporation into early childhood programs aligns with holistic educational goals, bridging movement-based learning and emotional development.

Traditional games are hypothesized to significantly enhance emotional intelligence in early childhood by promoting direct interaction, cooperation, and emotional expression. These culturally embedded games are expected to provide structured experiences that support the development of core emotional and social competencies in children aged 3 to 6 years.

This study aims to examine the effectiveness of traditional games in improving emotional intelligence in children aged 3 to 6 years through a literature review approach.

Material and Methods

Information Sources

Scientific articles were identified through a comprehensive search of both international and national academic databases. The international databases included Google Scholar, Scopus, Elsevier, and ResearchGate. National sources comprised the SINTA and Garuda databases. The search strategy involved the use of multilingual keywords such as "traditional games, " "emotional intelligence, " "children, " "adolescents, " and "social-emotional development." Keywords were applied in Indonesian, English, and other commonly used academic languages to ensure broader coverage.

Methodology

This study employed a Systematic Literature Review (SLR) approach based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The article identification process followed the PICO framework, which defined the Population (children aged 3 to 6 years), Intervention (traditional games), Comparison (not applicable), and Outcome (emotional intelligence) [18, 19].

In this review, the PICO elements were operationalized as follows:

• Population – defined strictly as children aged 3–6 years, based on study inclusion criteria

• Intervention – traditional games, either culturally specific or generically labeled as traditional play

• Outcome – emotional intelligence, identified through indicators such as empathy, emotional regulation, and cooperation

• Comparison – not applicable, as most studies lacked a formal control group.

The literature search was conducted using the Publish or Perish software in combination with multiple databases, including Google Scholar, Scopus, Elsevier, ResearchGate, SINTA, and Garuda. The search covered publications between 2014 and 2024 and applied multilingual keyword combinations relevant to traditional games and emotional development in early childhood. The search keywords for the articles are presented in Table 1.

Table 1. Article Search Keywords

PICO	Information
Population	Early childhood aged 3–6 years
Intervention	Traditional games
Comparison	–
Outcome	Emotional intelligence

Note: P = Population/Patient; I = Intervention; C = Comparison; O = Outcomes

The inclusion criteria were:

• The study focused on the relationship between traditional games and emotional intelligence

• Participants were children aged 3 to 6 years

• The article presented empirical data (qualitative or quantitative)

• Full-text peer-reviewed publication.

Exclusion criteria included:

• Lack of methodological transparency

• Irrelevance to the defined age range or intervention type

• Absence of emotional intelligence as a focal outcome.

The review process followed the PRISMA stages: defining criteria, identifying sources, screening titles and abstracts, filtering full texts, and synthesizing results. A descriptive qualitative content analysis was applied to identify patterns in how traditional games influence emotional intelligence. Findings were grouped by game type, emotional indicators (such as empathy, self-control, cooperation, and social awareness), and intervention characteristics. To enhance methodological reliability, the screening and selection of articles were conducted independently by two reviewers. Discrepancies in inclusion decisions were resolved through discussion and consensus. The selection process is illustrated in the PRISMA flow diagram (Figure 1).

As this review is based on secondary data, no primary data collection was conducted. The reliability of the synthesis was ensured through a rigorous selection of sources, based on methodological soundness and consistency of reported outcomes.

As this study involved a secondary analysis of publicly available literature, ethical approval and informed consent were not required.

Data Analysis

The final synthesis included eight empirical studies that met all inclusion criteria. These studies varied in methodological design and geographic origin but shared a focus on the use of traditional games as interventions for emotional development in early childhood. The analytical process was conducted descriptively using qualitative content analysis techniques. Each study was reviewed to extract information on the type of game used, the specific emotional intelligence indicators addressed (e.g. empathy, emotional regulation, cooperation), and the structure of the intervention. Findings were grouped thematically to identify consistent patterns and conceptual trends across studies. The use of a synthesis table enabled clear comparison of results and enhanced traceability of thematic categories.

Results

The results of this study consist of a synthesis of eight relevant articles that met the inclusion criteria. Each article was analyzed to identify the types of traditional games used, the specific emotional intelligence indicators targeted, the implementation context, and the age group of the participants. The studies also report the frequency and consistency of observed emotional outcomes across different interventions. To support clarity and transparency, the findings are summarized using tables and figures that map the relationship between traditional games and the development of emotional intelligence in early childhood.

The main characteristics of the analyzed articles are presented in Table 2.

To support the interpretation of the results, Table 3 presents the distribution of key variables across the included studies. It summarizes the types of traditional games used, the emotional intelligence components measured, research designs applied, and target populations described.

Overall, the most frequently targeted components of emotional intelligence across the reviewed studies were empathy, emotional regulation, and cooperation. These domains appeared consistently regardless of whether the interventions involved named traditional games (e.g., congklak, Balogo, Cublak-cublak Suweng) or general categories such as "traditional play."

In several studies, the specific games were not named. Instead, authors referred to the interventions in general terms (e.g., "local traditional games" or "play-based programs"), which may reflect cultural variation or informal labeling practices in the original contexts.

Four studies employed quantitative designs and reported measurable emotional outcomes. Among these, three showed statistically significant improvements in emotional intelligence indicators (e.g., $P < 0.05$), and one reported a 76% gain using N-Gain analysis. The remaining studies used

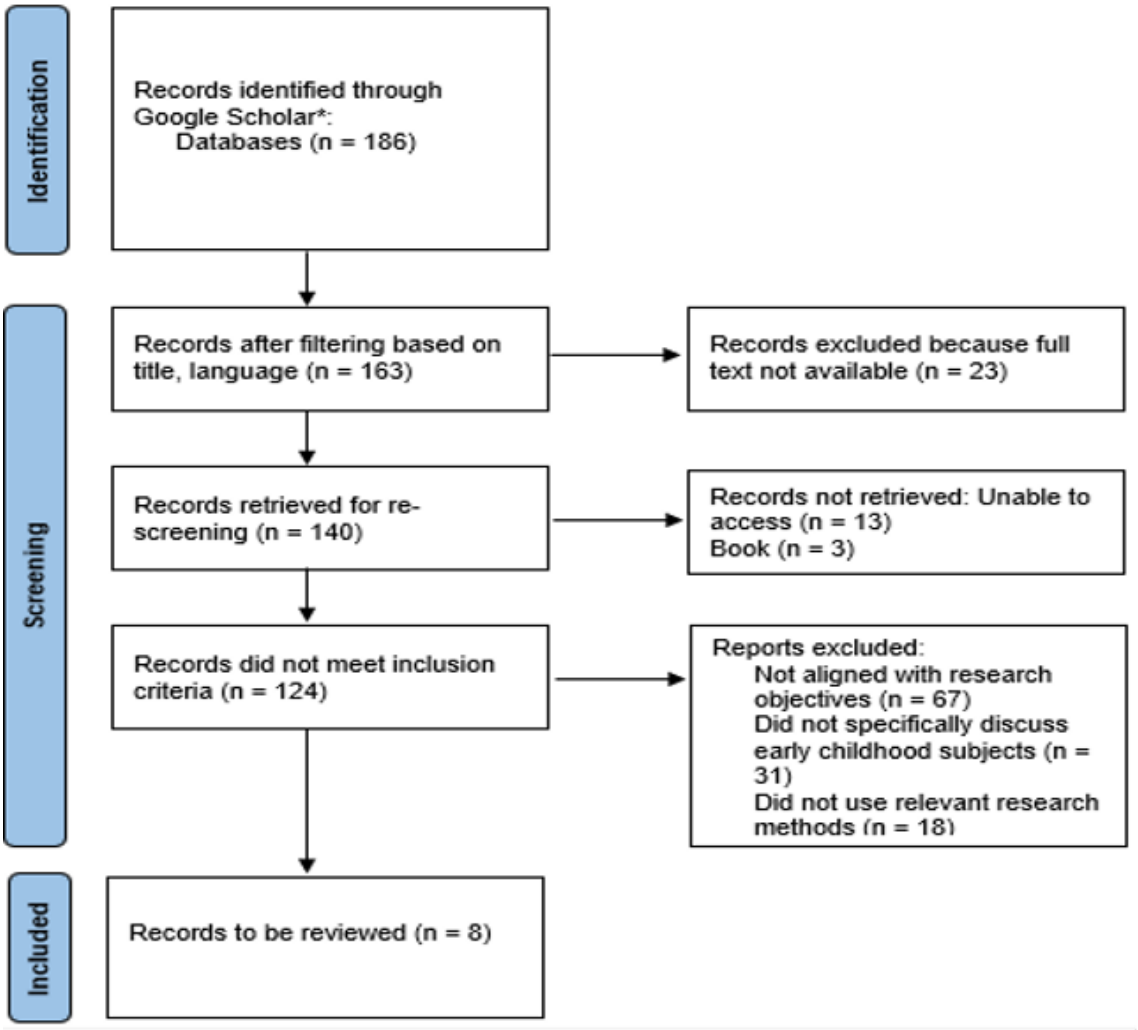

Figure 1. PRISMA Diagram Showing a Flow of the Study Selection

Table 2. Summary of Reviewed Studies on Traditional Games and Emotional Intelligence in Children Aged 3–6 Years

No	Author and Year	Type of Traditional Game	EQ Components Targeted	Age Group	Intervention Format / Duration
1	[21]	*Congklak*	Emotion recognition, expression, self-control, social bonding	Early childhood	Repeated play cycles with observation-based assessment
2	[22]	*Balogo*	General EQ score (measured via N-Gain)	Kindergarten children	Experimental design; N-Gain analysis (76%)
3	[23]	Not specified	Overall emotional intelligence	Elementary school	Single-group intervention
4	[24]	Multiple (not named)	Emotional intelligence (with statistical comparison)	Preschoolers	16 sessions; pretest-posttest control group design
5	[25]	Not specified	Emotional regulation, empathy, social interaction	Early childhood	Qualitative synthesis of game-based programs
6	[26]	Traditional Play Programs (TPPs)	Self-awareness, relationship management, regulation	Children in care centers	Mixed methods; focus on subdomains of EQ
7	[27]	*Cublak-cublak Suweng*	Empathy, cooperation, emotional regulation	Generation Alpha (early childhood)	Observational intervention
8	[28]	Not specified	Interpersonal intelligence (teamwork, emotional support)	School-aged children	Descriptive approach based on community practices

Table 3. Thematic Distribution of Key Variables Across Reviewed Studies

Variable	Frequency (n = 8)	Notes
Named Traditional Games	3 studies	Congklak, Balogo, Cublak-cublak Suweng
Unnamed/Generic Game Interventions	5 studies	Described as «traditional play» without specifying the exact game
Most Frequent EQ Components	6 studies	Empathy, self-control, emotional regulation
Use of Quantitative Measures	4 studies	Includes N-Gain scores, pre- post test comparisons (e.g., $P < 0.05$)
Descriptive/Qualitative Designs	4 studies	Observational or thematic analysis approaches
Experimental Design with Control Group	2 studies	Clear comparison between intervention and control groups
Focus on Early Childhood (3–6 years)	6 studies	Aligned with inclusion criteria of the review
Studies Conducted in Indonesia	5 studies	Cultural relevance and use of local games

qualitative assessments that highlighted observed gains in interpersonal behavior and emotional expression.

Discussion

This systematic review aimed to evaluate the effectiveness of traditional games in fostering emotional intelligence in children aged 3 to 6 years. Across the eight eligible studies, consistent patterns emerged showing that such games support the development of empathy, self-regulation, cooperation, and self-awareness. Despite variations in game types and research designs, the findings converge to highlight traditional games as meaningful contexts for early emotional learning.

Previous research has shown that structured traditional play can serve as an effective medium for emotional development in children. For example, [29] demonstrated that an integrative program called Harmonious Physical Education, which combines traditional games, sports, and group movement, enhances both intrapersonal and interpersonal emotional skills. These findings indicate that traditional games can be used not only for recreation but also as emotionally meaningful educational interventions.

The findings of this review are supported by theoretical and empirical frameworks in developmental and educational psychology. Vygotsky's sociocultural theory, which emphasizes the role of play in the internalization of social and emotional functions, provides a foundational perspective for understanding how children learn through interaction and symbolic activity [30]. This theoretical basis is clearly reflected in traditional games that require negotiation, turn-taking, and emotional feedback processing. These mechanisms are present in the games described in [21, 25, 26].

Emotional intelligence models, such as those developed by Mayer and Salovey or Goleman, suggest that emotional competence arises not only from reflection but also from immersion in socially complex situations [31]. The games evaluated in [24, 25, 27] place children in emotionally charged group dynamics where they learn empathy, regulation, and cooperation through active experience rather than explicit instruction.

Several studies included in this review, such as [22, 23, 24, 25, 26, 27], reported improvements in various emotional intelligence indicators following traditional game-based interventions. For example, [22] documented a high N-Gain score in kindergarten settings for the game Balogo, while [24] identified statistically significant emotional gains in a controlled design. These results represent findings extracted directly from the reviewed sample. In contrast, supporting insights from prior literature, including [29], provide a broader theoretical and empirical context by highlighting the emotional relevance of traditional play within integrated educational models.

Finally, [28] highlighted that traditional games enhance interpersonal intelligence, a construct closely associated with emotional intelligence. Through collective decision-making, expression of opinions, and shared emotional support, children developed social competencies that are fundamental at this early developmental stage.

While [21] explored emotional self-regulation through individual responses during play, [26] examined how group-based traditional games support relationship management and collective emotional problem-solving. This broadens the scope of emotional outcomes beyond personal competence to include socially co-constructed emotional knowledge.

In terms of educational application, the reviewed studies reflect methodological parallels with global social-emotional learning (SEL) programs. For example, the use of structured interventions in [22, 24] with measurable pre- and post-intervention outcomes aligns with evidence-based practices in international SEL research. In contrast, the activities in [21, 25, 27] emphasized child-led play,

spontaneous decision-making, and emotional negotiation within culturally meaningful contexts. This distinction is especially relevant for settings where standardized programs may not align with local culture or resources.

Another point of convergence with the broader literature is the adaptability of traditional games as tools for both formal and informal education. The findings in [24, 26, 27] demonstrate that when integrated into early childhood programs, these games can function as instructional strategies and culturally responsive practices that affirm children's lived experiences. Unlike externally developed interventions, traditional games reflect community values and real social situations, which enhances emotional authenticity and learning effectiveness.

Taken together, the evidence supports the conclusion that traditional games are not only consistent with contemporary theories of emotional learning but also offer distinctive pedagogical advantages. They integrate social-emotional development with cultural continuity, providing accessible and emotionally meaningful contexts for young learners.

Limitations and Future Research

The reviewed studies present several methodological limitations that constrain the generalizability of findings. Many of them involved small, non-representative samples and lacked detailed descriptions of the intervention procedures. In some cases, the assessment tools used to measure emotional intelligence were either unvalidated or inconsistently applied. Most studies were of short duration, which makes it difficult to determine whether the observed improvements in emotional intelligence are sustained over time. The concentration of research within a single national context also raises concerns about cultural bias and limits the broader applicability of the results. Furthermore, the lack of standardized intervention protocols complicates efforts to replicate findings and draw firm conclusions about causality. Future research should address these issues by using longitudinal designs, applying interventions in culturally diverse settings, and relying on validated emotional intelligence instruments. Comparative studies between digital and traditional games, as well as investigations into the effectiveness of teacher-led versus peer-guided gameplay, may help clarify underlying mechanisms of emotional development. In addition, identifying specific types of traditional games that support distinct emotional skills, such as impulse control, empathy, or social interaction, would contribute to the development of targeted, evidence-based educational strategies.

Practical Implications

Despite these limitations, the findings suggest that traditional games can be valuable tools in early childhood education. Educators can use these games to support the development of emotional intelligence in a natural and culturally embedded way. Traditional games are often inexpensive, require minimal equipment, and promote active participation, making them accessible in various educational settings. Incorporating traditional games into structured classroom activities may help children practice emotional regulation, cooperation, and empathy in real time. Furthermore, such games can support inclusive practices by engaging children of different backgrounds and developmental levels. They may also contribute to preserving cultural heritage through intergenerational transmission of play practices.

Conclusions

This systematic review examined how traditional games relate to the development of emotional intelligence in children aged 3 to 6 years. The analysis of eight studies suggests that these games are associated with improvements in emotional regulation, empathy, cooperation, and self-awareness. Traditional games offer structured social contexts where emotional learning can occur through culturally meaningful and interactive play. The findings point to the potential of integrating traditional games into early childhood education as a contextually relevant way to support emotional development.

Conflict of Interest

The authors declare no conflict of interest.

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ORIGINAL ARTICLE

Assessment of terminological density in scientific publications on physical culture

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Abstract

Background and Study Aim: Scientific publications in the field of physical culture demonstrate considerable diversity in terminological usage and structural organization. With increasing standards for the quality of academic writing, the need for an objective and quantitative evaluation of terminological density has become more pressing. The aim of this study was to develop and apply a method for automated assessment of terminological density in scientific articles on physical culture using adapted thematic dictionaries.

Material and Methods: The study was based on articles retrieved from the Web of Science (WoS) database. A total of 16 593 bibliographic records related to physical culture were extracted over the past five years. Two dictionaries were employed for analysis: the official Medical Subject Headings (MeSH) in XML format and a thematic dictionary constructed from the WoS document corpus. The analysis included full-text PDF articles from 12 scientific journals, of which 6 were categorized as Q3, 1 as Q4, 3 were indexed in DOAJ, and 2 were not indexed. Terminological density was calculated in Python using the pandas library and evaluated on a scale ranging from very low to high.

Results: The assessment covered 12 journals in the field of physical culture. An optimal density level (0.010–0.019) was identified in 2 journals (16.7%), corresponding to a "balanced use of scientific terminology." Three journals (25.0%) demonstrated low density (<0.01), characterized as "insufficient elaboration of the topic in scientific language". In 7 journals (58.3%), a higher density (0.020–0.039) was observed, interpreted as either an "attempt to enhance scientific rigor" or an "excessive terminological load".

Conclusions: The evaluation of terminological density provides an objective measure of the scientific style of publications in the field of physical culture. The differences identified across journals highlight variability in approaches to presenting scientific material. The integration of specialized dictionaries and the application of relative indicators offer a robust basis for ongoing monitoring and optimization of scientific discourse.

Keywords: terminological density, sport and exercise sciences, scientific publications, thematic dictionaries, academic discourse, Medical Subject Headings (MeSH), Web of Science, bibliographic analysis, quantitative evaluation, scientific style

Introduction

Contemporary scientific communication requires adherence to established standards of structure and content in scholarly publications. Among these standards, the use of professional terminology plays a central role, ensuring the accuracy of scientific expression, thematic identification of research, and effective indexing in digital databases. The application of precise scientific vocabulary influences not only the perception and interpretation of information but also the indexing of articles in major bibliographic systems such as Web of Science and Scopus. This, in turn, determines the visibility and citation impact of publications, as well as the overall influence of academic journals. Such practices provide a foundation for both quantitative and qualitative analyses of the linguistic dimension of scientific texts, reveal the depth of thematic elaboration, and contribute to addressing tasks related to the optimization of scientific discourse in the field of physical culture and sport.

In recent years, automated analysis of scientific texts has become an important tool in bibliometrics and the evaluation of research output. One of the key methods is TF-IDF (term frequency–inverse document frequency), which is applied to determine the significance of terms within a text [1, 2]. This approach is widely used for thematic indexing, keyword analysis, and the assessment of scientific publication quality [3, 4].

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In medicine and related disciplines, the MeSH (Medical Subject Headings) thesaurus, developed by the U.S. National Library of Medicine, is frequently applied [5]. It provides a standardized terminology and is extensively used in systematic reviews and in the classification of scientific articles [6, 7]. The Web of Science database also employs its own keywords, which are listed separately from the authors' keywords.

At the intersection of these approaches (TF-IDF and MeSH), effective methods have emerged for the quantitative and content-based evaluation of scientific publications. Their applicability has been confirmed in several studies, including those in the field of physical culture and sport sciences. Kiss et al. [8] conducted a bibliometric analysis of publications on sports nutrition using MeSH keywords and science mapping techniques to identify major research themes. Venâncio et al. [9] performed a bibliometric and scoping review to trace the evolution of research on strength training among competitive swimmers. Jagiello and Lochbaum [10, 11] applied Python-based algorithms to analyze publications in the pedagogy of physical activity. Yermakova [12, 13] employed topic modeling methods to investigate literature on sports injuries and rehabilitation.

The use of terminological dictionaries, both controlled (MeSH) [14] and empirical (constructed from WoS data), provides a more objective approach to evaluating terminological density. This enables a quantitative characterization of thematic rigor, scientific maturity, and the relevance of publications, as well as the comparison of journals and articles according to unified criteria.

The use of thematic lexicons, both manually constructed and automatically extracted from scientific databases, has long been applied in bibliometrics, thematic analysis, and the evaluation of scientific content. The effectiveness of controlled vocabularies (e.g., MeSH [5]) as well as empirically derived dictionaries (e.g., Keywords Plus from Web of Science [15]) has been well documented in the literature.

Scientometric analysis tools such as VOSviewer and SciMAT rely on frequency-based term dictionaries from WoS and Scopus for constructing science maps and thematic clusters [16, 17]. At the same time, the MeSH thesaurus [5] has traditionally been employed in biomedical analyses, including automatic classification of scientific texts [18], profiling of academic journals [Kim2016], assessment of thematic relevance [19], and standardization of density intervals [20]. Several studies suggest combining free keywords (WoS) with controlled descriptors [14] to improve the accuracy of thematic classification [21]. A similar approach was applied by Wang et al. in their analysis of literature on physical activity and health, where both WoS and PubMed data were used simultaneously [22].

Comparative studies of the terminological structures of Scopus and Web of Science have demonstrated that the combined volume of author keywords and Index Keywords in Scopus is more than twice that of the corresponding field in WoS [23]. Furthermore, van Eck and Waltman [24] showed that Scopus keywords are well suited for constructing thematic maps and publication clusters. Comparable approaches are implemented in software tools such as Bibliometrix, where author and indexed keywords from Scopus serve as the basis for semantic and co-word analysis [25].

Threshold values for interpreting terminological density are based on empirical observations and indexing standards. For example, Leblanc et al. demonstrated that incorporating a sufficient number of MeSH terms into the search strategies of systematic reviews significantly improves retrieval completeness, indirectly highlighting the importance of high terminological density [19]. Breuer et al. emphasized that concentrating key terms and identifying a "core" set of documents increases representativeness when analyzing reduced samples [26]. At the same time, values exceeding 4% may impair text readability even for specialists [27].

Within the framework of information standards, the U.S. National Library of Medicine recommends indexing publications using 5–15 MeSH terms per 1, 000 words, corresponding to a density of approximately 1–1.5% [5]. Similarly, Scopus employs keywords to enhance thematic search functions and provides the basis for automated topic matching [28].

Thus, despite the absence of a strict hierarchy, the terminological data in Scopus represent a well-grounded empirical resource for dictionary construction and the evaluation of scientific texts. Moreover, the practice of creating adapted dictionaries based on MeSH in combination with frequency-derived empirical terms from WoS and Scopus terminological data is supported in the literature and is methodologically justified.

Terminological density represents a quantitative indicator that reflects the proportion of specialized scientific terms within the total volume of significant words. This measure is widely applied in bibliometric studies, automatic indexing, and the evaluation of the scientific orientation of texts. The rationale for employing this approach lies in the attempt to objectively capture the thematic focus and academic style of scholarly publications.

In a study by Ding et al. [29], co-word analysis was used to construct maps of research directions in the field of information retrieval, demonstrating the effectiveness of frequency-based term analysis for identifying themes and subdisciplines. A similar approach was applied by Haunschild et al. [30], who utilized automatically generated Keywords Plus

terms from the Web of Science database to analyze publications on climate change. These findings confirmed the value of automatically extracted terminology for developing thematic profiles of scientific domains.

From the perspective of computational text processing, the TF-IDF method remains one of the most widely applied approaches for identifying significant terms. Wang [3] demonstrated that combining TF-IDF with semantic analysis enables the effective extraction of keywords from texts, including scientific publications. This approach can be used to evaluate both the density and orientation of the academic style of an article. In databases with well-developed controlled vocabularies, such as those in medicine, the MeSH thesaurus is extensively employed. Bekhuis et al. [31] examined the coverage of concepts related to comparative studies in MeSH and Emtree, underscoring the importance of standardized terminology in the systematization of scientific content. Similarly, Koloski et al. [32] demonstrated how neural network–based keyword extraction methods can be complemented by TF-IDF and aligned with pre-defined terminological lists, thereby enhancing the accuracy of thematic analysis.

To determine the appropriate number of documents for analyzing terminological density, the Pareto principle (80/20 rule) is often recommended. Valkanas and Diamandis argued that approximately 20% of publications may account for up to 80% of citations, reflecting the uneven distribution of scientific attention [33]. In bibliometric research, the Pareto rule is frequently applied to identify core journals, where about 20% of titles generate around 80% of citations or usage, thereby ensuring representativeness even with a reduced dataset [34].

Thus, terminological density can serve as a reliable indicator of scientific relevance, thematic precision, and stylistic rigor of texts. Its application is justified both in tasks of automated classification of publications and in expert evaluation of scholarly materials.

The assessment of terminological density in scientific articles makes it possible to identify their thematic orientation and to conduct a structural analysis of scientific rigor. However, excessive concentration of terms may indicate stylistic oversaturation and the use of "pseudo-scientific" vocabulary without sufficient semantic depth. This underscores the need to define an optimal range of terminological density.

Solnyshkina et al. [35] emphasized the importance of lexical density as an indicator of complexity and stylistic level in educational texts, which can also be applied to scientific publications. Recommendations of the U.S. National Library of Medicine [5] suggest that the number of MeSH terms should range from 5 to 15 per 1000 words, corresponding to a density of approximately 1–1.5%. According to Halliday's concept of lexical density [36], term overload (>4%) reduces accessibility and makes comprehension less effective, even for specialists.

Other studies provide indirect evidence supporting the proposed range of terminological density through textual descriptions or methodological approaches. Some works focus on linguistic analysis and the evaluation of the "scientificness" of texts, including terminological richness and distinctions between specialized and popular materials across subject areas [37, 38]. Other studies examine computational methods of text processing, including TF-IDF, topic modeling, automatic term extraction, and lexical density analysis, which may be employed to determine the relative proportion of terms in a text [39, 40].

One of the key factors influencing the accuracy of assessing terminological density in scientific texts is the consideration of synonymic and morphological variations of terms. Fu et al. proposed the SynGen method, which employs regularizers for synonym generalization in biomedical NER, thereby improving the completeness of concept extraction even beyond predefined dictionaries [41]. This is particularly relevant in the analysis of precise terms, where word forms and synonyms may differ substantially. Slater et al. [42] demonstrated that extending terms through inter-ontology synonymy significantly increases coverage in medical text analysis. Moreover, methods that combine contextual analysis with structural relationships enable the extraction of synonyms, hypernyms, and hyponyms, enhancing both terminological completeness and consistency [43]. In the field of NLP, Thießen et al. [44] showed that large language models (BERT, RoBERTa, GPT-3) are capable of detecting scientific synonyms through clustering of hidden representations, which directly contributes to more accurate term normalization.

Studies of terminological density in the context of physical culture illustrate approaches to identifying and quantitatively assessing terms in applied domains. For example, Pans et al. proposed a methodology for evaluating the terminological contribution of key concepts across different ranges of research [45]. Another approach demonstrated that collocations and derivative forms play a dominant role in shaping terminological density within sports-related vocabulary [46, 47]. The historical and cultural grounding of terminology, along with its standardization, enhances the relevance of professional communication and improves the efficiency of thematic searches [48, 49]. In digital sports discourse, the systematic identification and classification of terms help assess their frequency, context, and semantic variability, thereby improving sample representativeness

and fostering interdisciplinary interaction [50]. Corpus-based observations of synonymy and variability confirm that high terminological density is characteristic of specialized texts and reflects the specificity of individual sports [51]. In this regard, the thematic classification of sports terminology serves as a foundation for the quantitative evaluation of terminological composition and for analyzing the informational richness of materials [52].

Thus, the inclusion of synonyms and word forms in terminological dictionaries: increases the sensitivity of analysis without compromising specificity; accounts for linguistic variability in the expression of the same conceptual entity; standardizes terminological analysis in the evaluation of scientific texts; and enhances the robustness of assessments when analyzing large document collections.

A review of numerous studies has shown that assessing terminological density through the use of thematic dictionaries and structured metadata is an effective tool for exploring scientific discourse. Scholars emphasize that such approaches contribute to more objective comparisons of publications, the identification of research trends, and the standardization of scientific vocabulary across disciplines. These methods are equally applicable to the domain of physical culture and sport. However, although some publications have addressed linguistic or content-based analyses in this field, they have rarely focused on term-centered evaluations of full-text documents. Such studies do not fully reveal important aspects of scientific communication, including lexical rigor, thematic relevance, and terminological density. This highlights the need for a more comprehensive and systematic analysis of scientific publications in this area.

The aim of this study was to develop and implement a method for the automated assessment of terminological density in scientific articles in the field of physical culture using adapted thematic dictionaries.

Materials and Methods

Sources of Information

The Web of Science (WoS) platform was used as the primary database. A total of 16 593 bibliographic records of articles published over the past five years were retrieved based on the search query. From the selected corpus, five thematic frequency-based dictionaries of terms were compiled, containing the relevant keywords. In addition, the official Medical Subject Headings (MeSH) thesaurus [14], obtained in XML format (desc2025.xml), was employed.

Full-text articles in PDF format were collected from 12 Ukrainian journals indexed in WoS and/or Scopus: six journals categorized as Q3, one journal categorized as Q4, three journals indexed in DOAJ, and two journals without indexing. For each journal, articles were obtained from the first available issues published in 2025.

Study Design

The study employed a descriptive-analytical design incorporating bibliometric and linguistic methods. To construct the document corpus, a search query was formulated in the Web of Science (WoS) database using the following keywords: “physical activity” OR “physical education” OR “physical culture” OR “physical fitness” OR “aerobic exercise” OR “resistance training” OR “exercise physiology” OR “motor skills” OR “sports science” OR “athletic performance” OR “training load” OR “endurance” OR “strength training” OR “health-related fitness” OR “sports training” OR “youth sports” OR “exercise intervention” OR “exercise behavior.” The search was restricted to a five-year time frame and to articles published in English.

In addition to keyword filtering, six Web of Science subject categories were applied: Sport Sciences, Public Environmental Occupational Health, Education Educational Research, Hospitality Leisure Sport Tourism, Rehabilitation, and Physiology. These categories were selected as the most relevant to the field of physical culture and related disciplines. They encompass key dimensions ranging from sports science, pedagogy, health promotion, and rehabilitation to the biophysiological foundations of physical activity.

Beyond thematic relevance, the selection was also guided by the informational richness of these six subject categories (Table 1, Figure 1), which accounted for approximately 77.7% of all documents retrieved on the topic of physical culture over the past five years. By contrast, the next 14 categories contributed only 14.7% of publications, while an additional 37 categories represented about 6.7%. The remaining 50 categories contained fewer than 10 publications each, collectively amounting to less than 1% of the total dataset. This distribution provided the rationale for restricting the corpus to the most representative and thematically significant domains.

Table 1. Distribution of categories by number of publications

Group of Categories	Range of Publications per Category	Number of Categories
Six core categories	1400–6000	6
Next 14 categories	100–500	14
Next 37 categories	10–94	37
Remaining 50 categories	<10	50

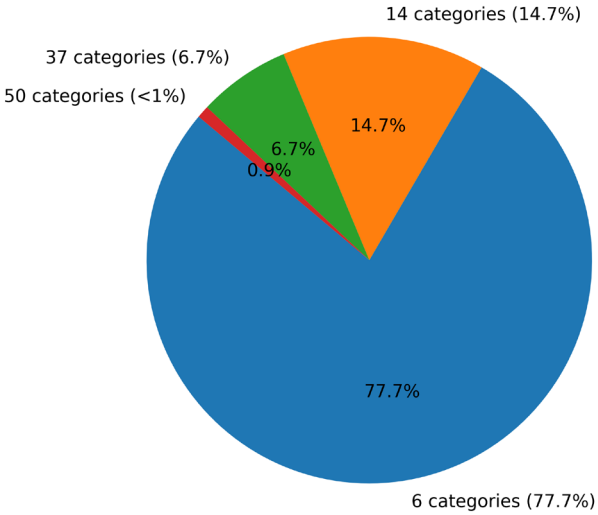

Figure 1. Distribution of publications across subject categories.

As a result, 16593 unique records that met the specified criteria were selected. Using the "Export Records to Plain Text File" function, the records were downloaded in batches of 1000 documents. A total of 17 batches were exported and subsequently merged into a CSV file for analysis.

For the unit of analysis, full-text PDF articles from 12 scientific journals were considered. The inclusion criteria comprised the availability of full texts, relevance to the subject area, and publication in English. Data processing involved extracting the main body of the articles (up to the "References" section), removing noise and technical symbols, eliminating short and insignificant words, and counting terms based on five thematic dictionaries, with attention to synonyms and word forms. All analyzed data are publicly available and do not contain any personal information.

Five different lexical dictionaries were created, each reflecting a specific aspect of the terminological composition of the texts. Each dictionary contained keywords and their frequency of occurrence in the corpus. In addition, the sixth dictionary, MeSH [14], was employed.

The dictionaries were constructed on the basis of 16593 bibliographic records. Using the CountVectorizer method [53], the 1000 most frequent n-grams (1–3 words) were extracted. From this set, the top 300 terms were selected for further analysis, in line with Zipf's law and recommendations for building controlled vocabularies, where the core semantic field is captured by a limited number of frequent units [54, 55].

Subsequently, semantic filtering was applied: constructions containing numbers, abbreviations, and phrases consisting solely of short words (⩽3 characters) were removed. From the cleaned dataset, the top 300 terms were retained as the most representative and thematically relevant.

For all dictionaries, a procedure was conducted to identify lexically and morphologically related forms. New terms were generated based on the stem or plural form of the original words. These derivative forms were grouped with their corresponding base terms and recorded in a separate column of the table.

For the first four dictionaries (Dictionary_1, Dictionary_2, Dictionary_3, and Dictionary_4), the most frequent expressions were extracted from the full dataset. Filtering was then applied to remove duplicates, non-specific and overly general phrases, as well as elements containing numerical characters. Newly generated derivative forms—synonymic and morphological variants—were added to the dictionaries. From the cleaned lists, the top 300 terms were selected, representing stable thematic categories used for the formal classification of publications. As a result, the following dictionaries were constructed:

- Dictionary_1 (AU). Created from the corpus of author texts, including TI (article title), AB (abstract), and DE (author keywords).
- Dictionary_2 (DE). Created from the corpus of author keywords (DE). A total of 16, 512 unique DE terms were identified.
- Dictionary_3 (ID). Created from the corpus of keywords added by WoS (ID). A total of 9, 018 unique ID terms were identified.
- Dictionary_4. Created from the combined corpus of author keywords (DE) and WoS-assigned keywords (ID).

In addition, Dictionary_5 (Adapted Dictionary) was developed, containing author terms that also appear in the MeSH thesaurus.

Finally, Dictionary_6 was compiled from the official version of MeSH, downloaded in XML format from the U.S. National Library of Medicine (desc2025.xml) [14]. From the hierarchical tree structure of MeSH, descriptors relevant to the core categories—Physical Activity, Sports, Rehabilitation, Health, and related domains—were extracted.

To evaluate the terminological structure of scientific publications, an algorithm for the automated processing of PDF files was developed in Python using the PyMuPDF (fitz) library and a set of predefined dictionaries.

After constructing five dictionaries and converting the sixth MeSH dictionary into an analyzable format, a term search was conducted across all six dictionaries. Unique matches with each dictionary were identified within the text of each article, and terminological density was calculated accordingly. A composite indicator (Overall Score) was then computed as the mean value of densities across all dictionaries, which was subsequently used to generate a ranking of articles within each journal. For each journal, the final dataset also included a summary row with the average values of the metrics.

The results were stored as CSV files for each

journal and were further used for cross-journal comparisons and the construction of summary analytical tables.

For the assessment of terminological density, the following indicator was applied:

Terminological density (or the relative weight of terms) represents the proportion of unique matched terms from a dictionary within the text of a scientific article relative to the total number of meaningful words. Density was calculated according to the formula:

$$D = M / N,$$

where D is the terminological density (relative weight), M is the number of unique terms identified in the text, and N is the total number of meaningful words (excluding stop words, numbers, short forms ⩽2 characters, and punctuation).

Density was computed separately for each of the dictionaries. Terms were considered matched if they appeared in the text in any of the accounted forms (synonyms or morphological variants). For each document, the following additional indicators were also calculated:

- the total number of meaningful words;
- the number of matched terms from each dictionary;
- the final combined score, defined as the average of the dictionary-based density values.

For the objective interpretation of terminological density (the relative weight of matched terms), an empirical interpretation scale was developed. The scale was grounded in evidence from contemporary studies on terminological analysis, bibliometrics, and information retrieval practices [19, 26, 27].

To interpret the results, a scale of terminological density was applied, based on empirically validated thresholds (Table 2). This approach made it possible to account for the relative position of an article within the overall distribution and to mitigate the influence of differences in text length and total number of terms. The scale ensured an objective comparison of publications regardless of their structure or length.

Table 2. Classification of terminological density levels in scientific texts

Terminological Density (Relative Weight)	Level	Interpretation
< 0.005	Low	Weak thematic saturation
0.005–0.01	Below average	Low saturation
0.01–0.02	Medium	Optimal saturation
0.02–0.04	Above average	Increased saturation
> 0.04	High	Terminological overload

To summarize the characteristics of terminological density across scientific journals, an algorithm for the automated compilation of an aggregated table was implemented based on previously calculated metrics for individual publications. The input data consisted of the term analysis results for each journal, stored in CSV format.

The algorithm included the following steps:

1. Loading the reference table (list_journals.csv) containing the correspondence between journal codes and their full titles.
2. Iterating through all final result files (results_*.csv) containing term analysis data for individual journals.
3. Extracting from each file the row marked as “Average for journal, ” which contained the mean metric values across the journal’s articles.
4. Assigning the full journal title based on the reference table and incorporating it into the aggregated list.
5. Constructing the final summary table, which included the following fields:
    - total number of words,
    - number and density of matched terms for each of the five dictionaries (WoS, MeSH, DE, ID, AU),
    - the integrated indicator of terminological density (Overall Score),
    - the journal’s rank position in the comparative list.

The summary table (journals_summary_form_de_id_au.csv) was saved in a separate directory for further analysis, visualization, and interpretation. This step ensured the transition from article-level analysis to journal-level generalization, enabling the identification and quantitative evaluation of differences in thematic density among journals.

For the quantitative evaluation of terminological density in scientific publications, all individual articles published in the selected journals were analyzed. In total, 103 articles were processed, and key terminological metrics were calculated for each based on five dictionaries.

Stage 1: *Construction of a unified article database*. At the first stage, results previously obtained for each journal were aggregated. From all tables containing metrics for individual articles, only the rows with data for specific publications (excluding the “Average for journal” row) were selected. For each article, the identifier of the corresponding journal was additionally recorded. All entries were merged into a single table containing:

- the number of words,
- the number and density of matched terms from the five dictionaries (WoS, MeSH, DE, ID, AU),
- the overall terminological density indicator (Overall Score).

The resulting table (all_articles_combined_de_id_

au.csv) included data for all publications and served as the basis for subsequent quantitative analysis.

Stage 2: Correlation analysis of terminological metrics. At the second stage, a correlation analysis of term densities across the five dictionaries was conducted. Spearman's correlation was applied to assess the degree of concordance among the rankings of terminological densities between articles, regardless of the scale of the values.

A matrix of pairwise Spearman coefficients was calculated for the following indicators:

- WoS Density
- MeSH Density
- DE Density
- ID Density
- AU Density.

Statistical Analysis

Data processing was carried out using the Python programming language (version 3.11). The pandas library was employed for data aggregation and analysis. Terminological density was calculated as a relative indicator, expressed as the proportion of matched terms from the five lexical sources (WoS, MeSH, DE, ID, AU) in relation to the total number of meaningful words in the text. At the stage of summary analysis, mean values were computed for each journal, ranking was performed according to the overall integrated score, and the percentage distribution of terminological density levels was determined based on the established classification. To normalize the results, a linear transformation scale ranging from 0 to 10 was applied, ensuring comparability of outcomes regardless of text length or number of terms. In addition, group-level analysis of density was carried out across the following categories: *very low*, *low*, *moderate*, *increased*, and *high* terminological density, which provided a quantitative characterization of the publication corpus. For the purpose of identifying relationships between lexical sources, correlation analysis was performed using Spearman's rank correlation coefficient at the level of individual articles. The resulting correlation matrix included all five terminological density indicators.

Results

Table 3 presents the values of terminological density for individual publications from one of the journals across the five dictionaries: WoS, MeSH, DE, ID, and AU. According to the established benchmark, the optimal range of terminological density is 0.01–0.02 terms per word. Comparison of the observed values with this reference range provides the basis for a qualitative assessment of the lexical structure of the publications.

The analysis of term density in the journal's articles (Table 3) revealed the following trends. A comparison of terminological density with the recommended range of 0.01–0.02 terms per word indicates a systematic exceedance across all five dictionaries. Hyper-saturation is most pronounced in the WoS and AU dictionaries, where values in individual publications reached 0.27 and 0.24, respectively—exceeding the upper threshold by a factor of 10–12. Even in the least saturated article (Overall Score = 0.039), density remained approximately twice above the recommended level. While the formalized dictionaries (MeSH, DE, ID) yielded comparatively lower values, they likewise exceeded the standard thresholds.

These findings indicate a high lexical density

Table 3. Assessment of terminological density in the journal

File	Word Count	WoS Hits	WoS Density	MeSH Hits	MeSH Density	DE Hits	DE Density	ID Hits	ID Density	AU Hits	AU Density	Overall Score	Rank
Article 1.pdf	615	169	0.2748	49	0.07967	68	0.11057	74	0.12033	149	0.24228	0.16553	1
Article 2.pdf	860	181	0.21047	52	0.06047	90	0.10465	96	0.11163	179	0.20814	0.13907	2
Article 3.pdf	480	89	0.18542	23	0.04792	32	0.06667	44	0.09167	87	0.18125	0.11459	3
Article 4.pdf	898	146	0.16258	38	0.04232	56	0.06236	66	0.07350	149	0.16592	0.10134	4
Article 5.pdf	2771	162	0.05846	57	0.02057	64	0.02310	77	0.02779	183	0.06604	0.03919	5
Article 6.pdf	3319	187	0.05634	50	0.01506	80	0.02410	100	0.03013	205	0.06177	0.03748	6
Article 7.pdf	2733	158	0.05781	44	0.01610	61	0.02232	76	0.02781	172	0.06293	0.03739	7
Article 8.pdf	3943	202	0.05123	63	0.01598	89	0.02257	100	0.02536	219	0.05554	0.03414	8
Average for journal (ppcs)	1952.38	161.75	0.13214	47.00	0.03726	67.50	0.05454	79.13	0.06353	167.88	0.13048	0.08359	4.5

Note. *WoS Density* — density of keywords derived from both author and WoS sources. *MeSH Density* — density of keywords corresponding to the MeSH standard. *DE Density* — density of author-provided keywords (DE). *ID Density* — density of WoS-assigned keywords (ID). *AU Density* — density of author terms derived from the title, abstract, and keywords of the publication. *Overall Score* — arithmetic mean of the five densities. *Rank* — position of the article in descending order of overall density score.

characteristic of scientific publications in applied domains. None of the articles fell within the normative range, underscoring the need to address standards of terminological load in the preparation and editing of scholarly texts.

As part of the summary analysis, an aggregated table was compiled to reflect the indicators of terminological density for 12 scientific journals in the field of physical culture. Table 4 presents the numerical values of terminological density for each of the five dictionaries (WoS, MeSH, DE, ID, AU), as well as the integrated indicator (Overall Score), which represents the mean value of the relative densities.

Using the normative interval of 0.01–0.02 terms per word as the reference range for terminological density, the following tendencies were identified:

1. The indicators of all journals substantially exceed the normative range across most dictionaries. This is particularly evident for:
    - *WoS Density* — with leading journals reaching values of up to 0.35;
    - *AU Density* — averaging above 0.20.
2. The densities of *MeSH*, *DE*, and *ID* are lower, but in many cases also exceed the normative range.
3. None of the journals fall entirely within the normative range across all dictionaries.
4. The top-ranked journal (Overall Score = 0.199) demonstrates the highest overall saturation, with marked exceedances across all densities, particularly WoS (0.355) and AU (0.247).

A more detailed interpretation of the obtained results is presented in Figure 2, which shows the deviations of actual terminological density values from the normative range (0.01–0.02 terms per word). The calculation was performed for each of the five dictionaries: WoS, MeSH, DE, ID, and AU. Positive deviation values indicate an excess over the upper limit of the norm, reflecting potential oversaturation of the text with terms.

The analysis of the data in Figure 2 indicates the following tendencies:

1. All journals demonstrate values exceeding the normative range across each of the five dictionaries. None of the indicators fall within the interval 0.01–0.02, confirming the oversaturation of texts with specialized terminology.
2. The largest deviations are observed in:
    - AU Density — up to +0.226 (journal N1),
    - WoS Density — up to +0.335 (the same journal), making these sources the primary contributors to terminological load.
3. Deviations in MeSH, DE, and ID are considerably lower but consistently positive (on average 0.03–0.09), reflecting a more moderate but still formalized level of terminologization.
4. Journal N1 stands out as the leader in all indicators, demonstrating the maximum deviations across all metrics.
5. Even the lowest-ranked journals (those with the smallest Overall Score) show deviations not falling below +0.03, which highlights the general

Table 4. Summary indicators of terminological density for 12 scientific journals in the field of physical culture

Rank	Journal	Word Count	WoS Hits	WoS Density	MeSH Hits	MeSH Density	DE Hits	DE Density	ID Hits	ID Density	AU Hits	AU Density	Overall Score
1	N1	1385.0	91.8	0.35507	26.8	0.12951	27.0	0.15644	33.0	0.10979	91.2	0.24655	0.19947
2	N2	1011.0	91.4	0.25944	29.6	0.08645	31.8	0.07651	36.4	0.09449	85.8	0.20547	0.14447
3	N3	1131.6	105.8	0.21123	30.2	0.05058	39.2	0.06708	45.4	0.07384	110.0	0.24393	0.12934
4	S1	1463.1	120.3	0.20116	36.1	0.06309	41.1	0.07521	48.8	0.06122	116.7	0.14768	0.10967
5	S2	1869.1	115.4	0.15521	33.7	0.04295	41.1	0.04887	48.6	0.05124	122.0	0.15498	0.09065
6	S3	1747.4	149.6	0.13725	44.4	0.04171	55.6	0.05259	66.4	0.06090	158.6	0.14628	0.08775
7	S4	1952.4	161.8	0.13214	47.0	0.03726	67.5	0.05454	79.1	0.06353	167.9	0.13048	0.08359
8	S5	1902.4	147.6	0.13194	42.5	0.03946	54.5	0.04684	63.5	0.04480	156.0	0.12183	0.07697
9	S6	2495.5	143.8	0.08506	43.9	0.02878	52.8	0.02708	65.6	0.03481	150.0	0.08496	0.05213
10	S7	3217.0	179.4	0.08186	56.2	0.02516	64.9	0.02733	81.7	0.03565	188.1	0.08163	0.05032
11	N4	2138.3	117.2	0.07679	34.8	0.02283	37.5	0.02524	49.8	0.03237	137.5	0.09389	0.05022
12	N5	4629.8	171.2	0.05370	52.6	0.01599	66.6	0.01872	82.2	0.02402	189.4	0.06051	0.03459

Note. The list of journals with abbreviations is as follows (N = non-indexed journals; S = journals indexed in WoS/Scopus): N1 – *Health Technologies;* N2 – *Health-saving Technologies, Rehabilitation and Physical Therapy;* N3 – *Physical Culture, Recreation and Rehabilitation;* S1 – *Rehabilitation and Recreation;* S2 – *Slobozhanskyi Herald of Science and Sport;* S3 – *Physical Education of Students;* S4 – *Pedagogy of Physical Culture and Sports;* S5 – *Physical Education Theory and Methodology;* S6 – *Health, Sport, Rehabilitation;* S7 – *Physical Rehabilitation and Recreational Health Technologies;* N4 – *Journal of Learning Theory and Methodology;* N5 – *Pedagogy of Health*

tendency toward terminological redundancy in the text corpus.

Thus, the analysis demonstrates that the terminological density of scientific publications in the field of physical culture systematically exceeds the established normative range.

To analyze the relationships between different lexical sources in the structure of scientific publications, a Spearman correlation matrix was calculated at the level of individual articles (Figure 3).

Five indicators of terminological density were considered (Figure 3):

1. WoS Density (lexicon from Web of Science),
2. MeSH Density (medical subject headings),
3. DE Density (keywords from descriptions),
4. ID Density (identifiers),
5. AU Density (author keywords).

The data in Figure 3 indicate the following tendencies:

1. All correlations fall within the range of 0.964 to 0.991, reflecting a high level of consistency in term distribution across the dictionaries.
2. Particularly strong associations are observed between:
    - WoS and AU (r = 0.991), indicating the proximity of author-provided vocabulary to the general scientific terminology actively used in the articles.
    - DE and ID (r = 0.981), showing a strong relationship between formalized lexemes from descriptions and index tags.
3. AU Density integrates into the correlation structure as reliably as the other indicators, confirming its importance in modeling the terminological profile of the text.

The results demonstrate the complementarity of lexical dictionaries in the analysis of scientific publications. The high degree of correlation confirms that terminological density possesses a stable structure regardless of the type of term source. This enables the use of both combined and isolated dictionaries in semantic evaluation, thematic mapping, and editorial analysis.

Discussion

The aim of this study was to develop and test a method for the automated assessment of terminological density in scientific publications in the field of physical culture using adapted lexical dictionaries. The obtained results confirmed the effectiveness of the proposed approach: all 12 analyzed journals demonstrated moderate, increased, or high levels of terminological saturation according to the WoS and MeSH scales. Particularly high density was observed when using the WoS dictionary, which is likely associated with the inclusion of author keywords and the stylistic features of the texts. Terminological density based on MeSH ranged from optimal to high levels, indicating the gradual integration of biomedical terminology into scientific publications on physical culture and sports.

Our results are consistent with previous studies that addressed issues of lexical saturation and its consequences. For example, Haunschild et al. demonstrated that the automatic use of Keywords Plus from WoS substantially increases term density and may overload the text [30]. Kiss et al. [8] and Venâncio et al. [9] emphasized the variability of terminological structures in sports-related publications, which is also confirmed by our observations.

Lu et al. [56] showed that the analysis of author keywords' frequency can effectively reveal thematic trends; however, such an approach carries the risk of terminological redundancy. Another study [57] employed automatic identification of data-related articles, which also relied on the detection of specific key expressions. These findings indirectly confirm that our method of quantifying terminological density highlights the same issue – concentrations of terms above the optimal level.

Moreover, Kim and Kim [58] demonstrated that even emerging scientific fields (e.g., the metaverse and sport) are characterized by the active introduction of specific terminology, which does not always align with established standards. This finding resonates with our conclusions: local publications in the field of physical culture often rely on their own lexical frameworks, thereby widening the gap with international descriptors.

The novelty of our study lies in the use of two types of dictionaries: controlled (MeSH) and empirical (WoS) for the analysis of the publication corpus. This approach made it possible to identify the distinction between standardized vocabulary and authorial practice, which has rarely been considered in previous research. Unlike studies with a narrow focus, our journal-level comparison expands the scope of bibliometric expertise and provides more generalized conclusions. A similar approach was applied by Hammerschmidt et al. [59], who conducted a bibliometric analysis of publication activity and thematic dynamics across five leading sport management journals over the period 2011 to 2020. Likewise, Shilbury [60] examined citation patterns in several sport management journals and emphasized the importance of journal-level analysis for understanding academic influence and citation structures.

In addition to integrating two dictionaries, a significant element of novelty was the creation of a domain-specific dictionary based on 16593 bibliographic records from the Web of Science database over the past five years. Unlike ready-made controlled resources, this dictionary reflects

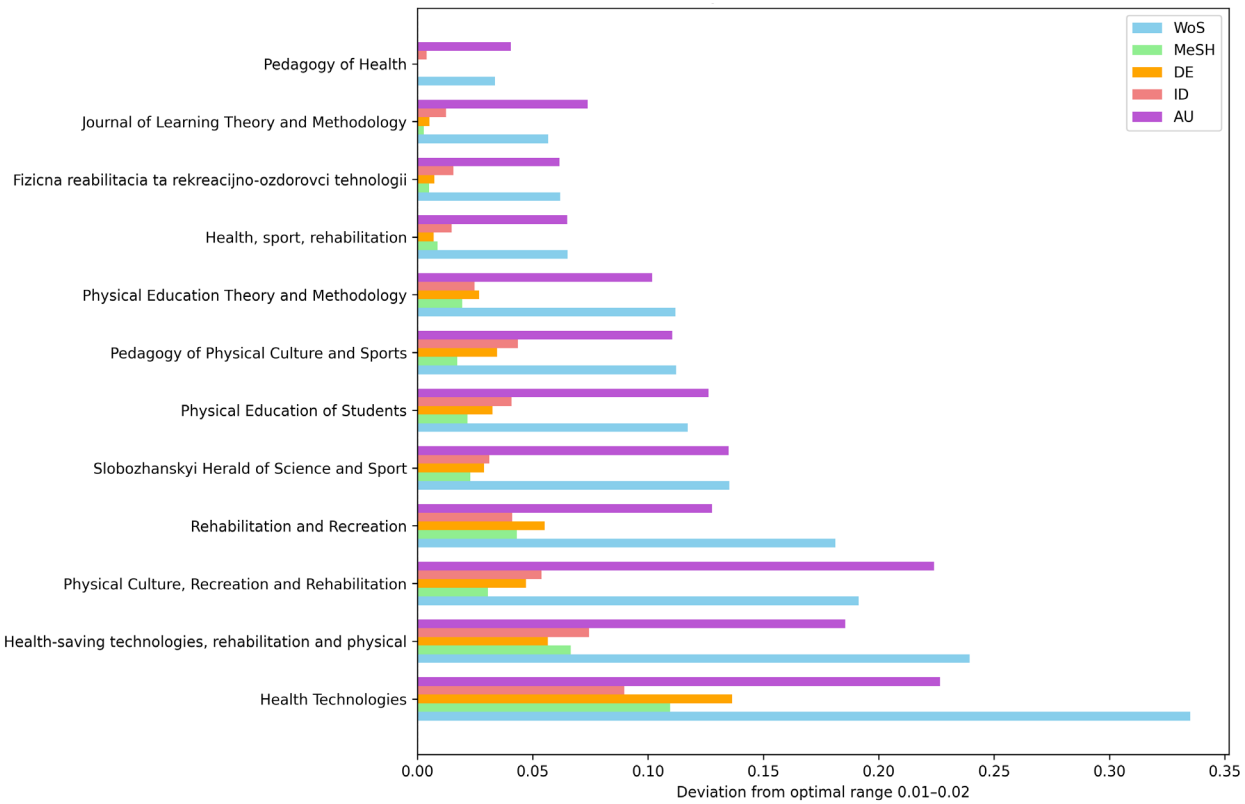

Figure 2. Deviations of terminological density from the normative range (0.01–0.02)

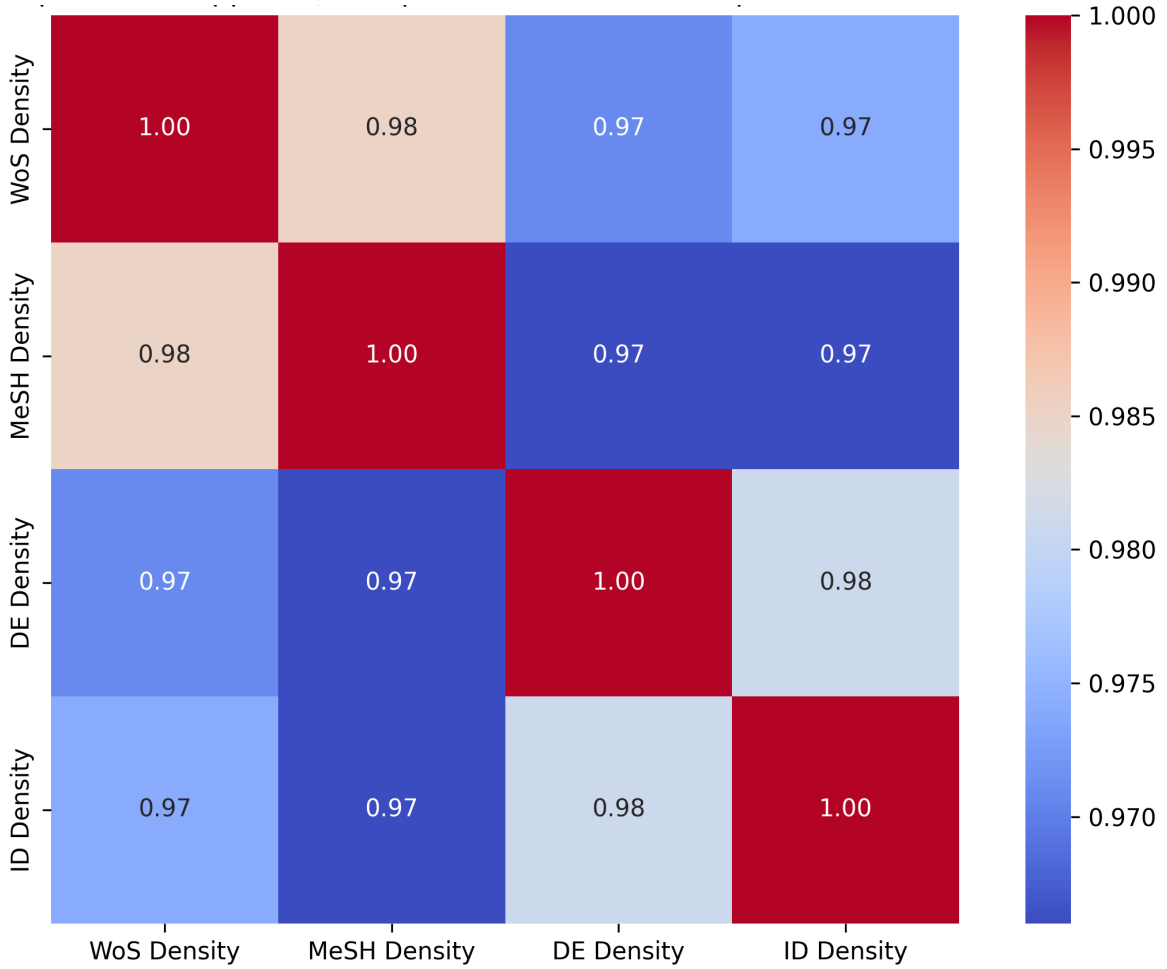

Figure 3. Spearman correlation matrix at the level of individual articles

the actual vocabulary of scientific publications in the field of physical culture. It represents stable expressions and professional terminology. Similar practices have a strong basis in the international research tradition. For example, Yan et al. [61] proposed a domain-independent method of term extraction for the identification of disciplinary dictionaries from full-text articles. Another study demonstrated the potential of a corpus-based approach for the automatic construction of semantic lexicons [62]. A new approach to the semi-automatic creation and expansion of a multilingual terminological thesaurus was presented by Horák et al. [63]. These examples show that the development of specialized dictionaries is a recognized direction in scientometrics and computational linguistics. However, the application of such a practice in the field of physical culture, based on such an extensive corpus of sources, has not been identified in the available data.

Another aspect of novelty is the high degree of automation in the assessment of terminological density. Unlike traditional content-analytical studies, we implemented algorithms for automated extraction of text from PDF files, corpus cleaning, consideration of word forms and synonyms, as well as the calculation of relative terminological density using Python (libraries pandas, re, fitz). This approach ensures reproducibility, eliminates subjective errors, and allows the processing of large datasets. Comparable methods of automation are reported in bibliometrics and computational linguistics. For example, Riloff and Shepherd [62] demonstrated the potential of corpus-based approaches for building semantic lexicons. Another study used automatic term extraction from full-text publications [61]. Horák et al. [63] showed the effectiveness of semi-automatic construction and expansion of a multilingual thesaurus. Such approaches increase the objectivity of evaluating publication practices [64]. In our case, these principles were applied for the first time to the evaluation of scientific journals in the field of physical culture. No similar approaches were identified in the available sources.

The approach applied in our study, which integrated two dictionaries supplemented with synonyms and word forms, provided more accurate terminological matching and increased the sensitivity of the analysis. This is consistent with the recommendations of Manning and Schütze [54] and Ahmad et al. [65], who emphasized the importance of reducing variability in academic writing. Our results also revealed a high correlation of metrics across the dictionaries, which confirms the stability of terminological density structures and demonstrates the applicability of automated methods for semantic evaluation of scientific publications.

The developed scale of terminological density based on the MeSH and WoS dictionaries demonstrated the ability to objectively classify publications and compare journals with each other. This expands the toolkit of bibliometrics and editorial practice by identifying imbalances in scientific style. Similar to the findings of Ahmad et al. [65], who showed differences in academic writing across disciplines, our scale reflects lexical specificity and can be used to adjust publication practices. The use of scales to measure textual complexity and terminological saturation is well established in linguistics and bibliometrics: Halliday [36] introduced the concept of lexical density as an indicator of text complexity; Solnyshkina et al. [35] applied readability formulas for building scales of educational texts; Leblanc et al. [19] demonstrated that the number of MeSH terms in systematic reviews can serve as a basis for standardized density intervals; Breuer et al. [26] proposed a scale for identifying the "core documents" based on the concentration of key concepts; Nasseri and Thompson [66] highlighted the significance of lexical density and diversity for distinguishing L1 and L2 texts; Bakuuro [67] linked lexical density with readability and perceived text complexity. However, in studies on physical culture and sport, similar scales have not been identified. Existing research has focused mainly on citation analysis and conceptual apparatus: Khatra et al. [68] conducted a bibliometric review of the most cited articles in sports medicine, and Staunton et al. [69] addressed the misuse of the term "load". Yet these studies did not include measurement of terminological density, which underscores the methodological novelty of our proposed scale, adapted for analyzing publications in the field of physical culture.

Thus, the proposed scale goes beyond existing bibliometric approaches and demonstrates methodological innovation, as it is the first to focus on measuring terminological density in publications on physical culture. The development of this direction is closely related to the automation of text analysis, which allows for broader applications and greater objectivity in the assessment of publication practices.

The characteristics of publications in the field of physical culture are shaped by the interdisciplinary nature of this domain, where pedagogy, sports medicine, physiology, and psychology intersect. Terminological density in such texts arises from a combination of specialized concepts ("load, " "adaptation, " "motivation, " "injury prevention") and a more general scientific vocabulary. This balance influences how texts are perceived by both professional and academic audiences. Unlike medicine or pedagogy, where terminology is more established, sports science demonstrates greater variability and frequent borrowing of concepts, which highlights the need for objective metrics in text evaluation.

In this context, bibliometric studies in sport have so far focused primarily on citation analysis and the identification of leading research areas. For instance, Khatra et al. [68] reviewed the most cited publications in sports medicine, showing the dominance of clinical and physiological research. Staunton et al. [69] drew attention to the misuse of the term "load, " underlining the importance of clarifying and standardizing terminology. However, none of these studies addressed the measurement of structural lexical saturation. The proposed scale of terminological density thus fills this gap by providing a quantitative tool for evaluating texts in the field of physical culture.

The application of the developed scale in this field has both theoretical and practical relevance. On the one hand, it provides editorial boards of national journals with an objective tool to assess manuscript quality in comparison with international standards. On the other hand, it offers authors a means to adjust their academic writing strategies in accordance with indexing requirements. This is particularly significant in the context of increasing competition among journals, where a balanced use of terminology becomes a marker of academic maturity and an important factor of international visibility.

In scientific literature, terminological density is regarded as an indicator of both the quality and complexity of academic texts. This interpretation originates from linguistic studies on translation and language [70], while a number of applied works have demonstrated its significance in fields such as healthcare and education, where terminology serves as a marker of professional quality and suitability of publications for indexing [56, 71, 72]. These studies confirm that the balance between terminological richness and clarity of expression directly affects the perception of research articles and their integration into the international academic space. In the field of physical culture, this balance is particularly critical, as publications are simultaneously addressed to the academic community and to practitioners in sport and education. Thus, the approach requires clarity of language while maintaining scientific rigor.

Our study extends this approach to the field of physical culture. The analysis of texts from leading Ukrainian journals demonstrated that terminological density can serve as an indicator of academic maturity and readiness of publications for international communication. The use of quantitative and bibliometric methods has already been established in related domains of physical literacy and physical activity. For instance, Mendoza-Muñoz et al. [73] conducted a global review of publications on *physical literacy* employing spatial and thematic visualization. Similarly, Memon et al. [74] analyzed the most cited studies on sedentary lifestyle, highlighting the need for qualitative indicators to assess textual influence. Li et al. [75] examined the thematic scope of research on physical activity and health in the context of osteoporosis, underlining the relevance of quantitative assessment methods in sport and health sciences. In addition, Arnal Gómez et al. [76] applied bibliometric techniques to analyze a physical therapy journal on aging, identifying key journals and citation trends. Furthermore, Buhin Pandur et al. [64] demonstrated the potential of topic modeling in social sciences based on Web of Science data, confirming the versatility of such approaches in interdisciplinary research.

In the context of growing competition and the need for indexing in international databases, terminological density can serve as a tool for evaluating both authorial writing strategies and editorial policies in journals on physical culture. This opens the possibility of comparing different domains of sports science, from biomechanics and sports medicine to pedagogy of physical culture, thereby identifying their degree of terminological maturity.

Thus, the analysis demonstrated that terminological density is a reliable indicator of the academic quality of publications, and its systematic excess in texts on physical culture indicates the need to adjust editorial standards. The integration of controlled and empirical vocabularies, taking into account synonymy and word forms, provides a basis for objective analysis and can be extended to other disciplines. For editors of journals on physical culture and sport, such a scale may serve as a practical tool for quality control of manuscripts, helping to identify excessive terminology, justify editorial revisions, and increase the transparency of author requirements in preparation for indexing. Future prospects include the use of contextual language models and more advanced morphological processing to deepen the analysis. A further step in the field of sports science may involve automated monitoring of terminological density in specific areas (sports medicine, training loads, student physical activity), which will make it possible to track the dynamics of disciplinary development.

Limitations

Several limitations should be acknowledged. Lemmatization and morphological normalization of terms were not fully implemented, which may have resulted in a partial loss of accuracy when calculating terminological density. In addition, the study was limited to a sample of 12 journals, which reduces the generalizability of the findings. Differences in indexing policies of WoS, Scopus, and PubMed may also have influenced the interpretation of the results. It is important to note that the focus on journals in physical culture and related fields limits the applicability of the conclusions

to a broader range of scientific disciplines. Future research should expand the sample of journals in sports science to refine the identified trends and enhance the reliability of generalizations.

Conclusions

The study demonstrated that terminological density can be regarded as a reliable indicator of the academic quality of publications in the field of physical culture and sports. The proposed scale, based on a combination of controlled and empirical vocabularies, showed methodological novelty and created opportunities for the objective comparison of journals, as well as for identifying imbalances in style and academic writing standards.

The analysis revealed that a high level of terminological density does not always correspond to the academic maturity of a text and may indicate the need for editorial adjustments. At the same time, a balanced use of terminology supports the integration of publications into the international scientific community, enhances their citation potential, and increases the transparency of research communication.

The findings confirm the potential of applying terminological density scales for evaluating publishing practices in physical culture and related disciplines. Further development should focus on the automation of text analysis, the expansion of the journal sample, and the use of contextual language models, which will enable deeper interpretation and improve the reproducibility of results.

Conflict of Interest

One of the authors (Sergii Iermakov) serves as the Editor-in-Chief and Publisher of this journal. To ensure an objective review process, the manuscript was handled by an independent editorial board member, and the peer review was conducted by external reviewers who had no affiliations with the authors. The Editor-in-Chief did not participate in the review or editorial decision-making process regarding this manuscript. The other co-authors (Georgiy Korobeynikov and David Curby) declare that they have no conflict of interest related to this publication.

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ORIGINAL ARTICLE

Effects of a 12-week extracurricular resistance training program on physical fitness parameters in adolescents: a controlled quasi-experimental study

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Abstract

Background and Study Aim: Physical activity during adolescence is essential not only for healthy growth but also for maintaining mental balance and recovery from everyday stress. In India, many schools lack structured recreational fitness programs, which limits opportunities for students to engage in health-oriented activity. Resistance training, while often considered a performance method, may also function as a tool for recreation and rehabilitation. The aim of this study was to evaluate the effects of a 12-week structured resistance training program on physical fitness and to examine its recreational and rehabilitative relevance for adolescents aged 13–16 years.

Material and Methods: Ninety-nine students (IG = 50; CG = 49) from two public schools in North Delhi participated. The intervention group undertook three weekly 60-minute resistance training sessions for 12 weeks, while the control group continued regular school activities. Outcomes included muscular endurance, power, speed, aerobic capacity, balance, coordination, flexibility, and BMI. A 2×2 mixed MANOVA tested Group × Time effects, followed by repeated-measures ANOVAs and paired t-tests. Effect sizes were reported using η^2 and Cohen's d.

Results: Significant Group × Time interactions were observed for muscular endurance and power, including sit-ups ($\eta^2 = 0.23$, $p < 0.001$), push-ups ($\eta^2 = 0.19$, $p < 0.001$), and broad jump ($\eta^2 = 0.26$, $p < 0.001$). Speed improved significantly in the 20-m sprint ($\eta^2 = 0.14$, $p < 0.001$). Within the intervention group, large effect sizes were found for sit-ups ($d = 1.20$), push-ups ($d = 1.07$), and broad jump ($d = 1.35$). Moderate gains were detected in countermovement jump, aerobic capacity, lateral jumps, and balance. Flexibility and BMI did not change, confirming that adaptations were domain-specific.

Conclusions: A structured 12-week resistance training program proved safe, feasible, and effective in enhancing strength, power, speed, and endurance among adolescents. Beyond physiological outcomes, the program demonstrated recreational and rehabilitative value by providing a supportive context for recovery, stress reduction, and long-term engagement in active lifestyles. These findings support the integration of resistance training into school-based physical education as a model for recreation- and rehabilitation-oriented practice.

Keywords: adolescents, resistance training, school-based program, physical fitness, recreation, rehabilitation, health promotion

Introduction

Adolescence represents a period characterized by pronounced physical, psychological, and social changes. During this time, lifestyle habits are formed that can influence health and well-being later in life. Increasing sedentarism, driven by academic pressures, screen-based activities, and limited opportunities for structured exercise, creates challenges for maintaining adequate fitness among adolescents. These difficulties have broad implications for health and daily functioning.

In this context, physical education extends beyond instructional teaching. It is a dynamic and interdisciplinary domain that intersects with psychological, social, and scientific dimensions of adolescent development [1]. Participation in sports and physical exercise supports musculoskeletal growth and offers experiences that enhance both physical and emotional well-being [2]. Regular activity during adolescence is essential for promoting fitness, including cardiorespiratory endurance, muscular strength and endurance, body composition, and flexibility [3]. However, several studies have documented a secular decline in youth fitness levels over recent decades [4].

Childhood and adolescent obesity is recognized as a major public health challenge with far-reaching implications for health and functional capacity. Evidence shows that obesity is associated with poor overall well-being, functional limitations, and long-term risks [5, 6, 7]. The relationship between physical health and psychological outcomes is equally important, as adolescents with poor health are more

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vulnerable to emotional distress [8]. Adolescence is also a period of rapid growth and maturation, during which puberty leads to marked changes in body size, composition, and physiology [9, 10]. For example, longitudinal monitoring has shown that obese teenagers may develop increasing arterial stiffness and elevated diastolic blood pressure [11]. Mental health challenges among youth are likewise associated with reduced physical activity, often compounded by social isolation, stigma, academic pressures, and illness [12, 13, 14].

At the same time, global childhood obesity rates have escalated in parallel with declining participation in vigorous physical activity [15, 16, 17]. Active lifestyles during early life are therefore essential for healthy growth, favorable body composition, and psychological well-being [18, 19]. After-school programs (ASPs) help overcome barriers such as cost, transportation, and time constraints. They also make use of social and environmental facilitators [20, 21, 22, 23]. Beyond improving fitness, such programs may enhance psychosocial outcomes and even academic performance [24, 25, 26, 27].

The rising prevalence of overweight and obesity among adolescents is a serious concern. Excess weight often persists into adulthood, where it increases the risk of chronic disease [28, 29]. Overweight adolescents sometimes demonstrate higher absolute strength due to greater muscle mass recruitment. However, this advantage does not necessarily translate into better functional fitness [30, 31]. In India, studies have documented high rates of physical inactivity and low fitness levels among school-going adolescents [32], highlighting the urgent need for accessible interventions.

Resistance training represents one such intervention. It contributes to weight management by increasing lean mass and basal metabolic rate [33], and it also improves bone strength, posture, cardiovascular health, body composition, and self-esteem [34, 35]. Compared to low-intensity activities, resistance training requires higher energy expenditure and is particularly effective in addressing adolescent obesity [36, 37, 38]. Long-term adaptations include muscle hypertrophy, metabolic efficiency, and improved endurance, which together support greater engagement in physical activity [39, 40, 41, 42]. Research has consistently shown 30–50% strength gains over 8–20 weeks, reinforcing motivation and positive exercise experiences [43, 44, 45]. Meta-analyses confirm that after-school resistance training programs are safe and effective. They enhance strength, power, and motor skills, while also reducing metabolic risks [46, 47]. Accordingly, global guidelines recommend that school-aged youth participate in muscle-strengthening activities several times per week [48, 49].

The pedagogical value of structured resistance training extends beyond physical health. Improved muscular fitness supports motor competence, confidence, and self-efficacy, which in turn encourage lifelong engagement in physical activity [19, 20]. Integrating resistance-based interventions into school curricula aligns with the goals of physical education, including the promotion of physical literacy, resilience, and holistic student development [21]. However, many Indian schools do not offer such programs, leaving a significant gap in the curriculum.

Although extensive evidence from Europe and North America has confirmed the benefits of resistance training for youth in enhancing strength, power, and coordination [4, 47, 50], these findings remain largely underexplored in South Asian populations. In India, particularly in government-run public schools with limited resources, structured resistance training opportunities for adolescents are rare.

Analysis of research findings has shown that resistance training can significantly improve strength, motor competence, and overall health outcomes in adolescents. Researchers emphasize that structured programs implemented in school environments provide not only physiological but also pedagogical benefits, contributing to confidence, resilience, and long-term engagement in physical activity. At the same time, the lack of systematic integration of such interventions into school practice continues to limit their potential impact, which creates the basis for further applied research in this area.

In addition to their training benefits, after-school resistance programs can be considered a form of recreational activity that provides adolescents with opportunities to recover from academic stress and sedentary routines. Such structured recreational formats help to maintain physical and mental health, creating a foundation for resilience and long-term well-being.

The present study does not claim methodological innovation but rather contextual novelty, as it adapts established EUROFIT-based approaches to an underrepresented demographic. By implementing a structured after-school program for boys and girls in real-world school environments, the research evaluates feasibility, effectiveness, and potential integration into school-based physical education. Building on these considerations, the aim of this study was to evaluate the effects of a 12-week structured resistance training program on physical fitness and to examine its recreational and rehabilitative relevance for adolescents aged 13–16 years. It was hypothesized that participants in the intervention group would demonstrate greater improvements across fitness parameters compared to peers engaged solely in routine school activities.

Materials and Methods

Participants

Initially, 112 secondary school students aged 13–16 years were screened from two public schools in North Delhi. After applying inclusion and exclusion criteria, 99 healthy students (52 boys and 47 girls) were retained. The intervention group included 50 participants, and the control group included 49.

A priori power analysis was conducted using G*Power 3.1.9.7 for repeated-measures ANOVA (within–between interaction). Based on an expected medium effect size ($f = 0.25$), $\alpha = 0.05$, power = 0.80, correlation among repeated measures = 0.5, and $\varepsilon = 1$, the required total sample size was 82 participants. The final sample of 99 exceeded this threshold, ensuring sufficient statistical power to detect moderate Group × Time effects.

The inclusion criteria were: age between 13 and 16 years, enrollment in the school's after-school program, medical clearance for moderate-intensity physical activity, and willingness to participate in all training and testing sessions. Each participant provided written informed assent, accompanied by parental or guardian consent. Two participants (one in each group) withdrew for personal reasons unrelated to the intervention. All remaining participants completed at least 90% of sessions.

Table 1 presents the baseline characteristics of participants in the intervention (IG) and control (CG) groups. Both groups were comparable in terms of age, sex distribution, and BMI categories. The majority of participants were within the healthy weight range (74% in IG; 73% in CG). No significant between-group differences were observed (all $p > 0.20$), indicating equivalence before the intervention.

Table 1. Participant demographics

Demographic	Intervention (n = 50)	Control (n = 49)
Age (years)	14.6 ± 1.1	14.4 ± 1.2
Age range (years)	13–16	13–16
Gender (M/F)	26 / 24	26 / 23
BMI category: Underweight	3 (6%)	2 (4%)
BMI category: Normal weight	37 (74%)	36 (73%)
BMI category: Overweight	6 (12%)	7 (14%)
BMI category: Obese	4 (8%)	4 (8%)

The data presented in Table 1 show that BMI categories were defined using age- and sex-specific percentiles. The majority of participants fell within the healthy weight range (5th–85th percentile). The proportions of underweight and overweight/obesity were small and comparable between groups. No significant between-group differences were found for any demographic variable (all $p > 0.20$), supporting the comparability of IG and CG at baseline.

Study Design

This study employed a quasi-experimental pre–post controlled design with intact class allocation. Two school classes were assigned as the Intervention Group (IG) and Control Group (CG), without randomization, to minimize disruption to school routines. Baseline equivalence between groups was confirmed before the intervention.

The 12-week program was structured not only as a resistance training intervention but also as a recreational activity designed to counter sedentary behavior, alleviate academic stress, and promote recovery and resilience. This framing allowed the study to assess the feasibility of integrating resistance training into school practice as a health-oriented approach consistent with recreational and rehabilitative objectives.

The recruitment and allocation process is illustrated in Figure 1.

Allocation and Bias Mitigation

Participants were assigned to either the Intervention Group (IG) (n = 50) or the Control Group (CG) (n = 49) by intact class allocation, to minimize disruption to school routines. While this quasi-experimental approach may introduce potential selection bias, baseline equivalence was confirmed: there were no significant between-group differences in age, gender distribution, BMI categories, or baseline fitness measures (all $p > 0.10$). To further mitigate bias, statistical adjustments were applied using mixed MANOVA/ANOVA models, and exact p-values with effect sizes were reported. Although full participant blinding was not feasible in this school-based intervention, all outcome assessments were performed by trained evaluators blinded to group allocation. Data entry and statistical analyses were conducted independently by a researcher not involved in training supervision, thereby reducing detection and reporting bias.

The exclusion criteria included the presence of any musculoskeletal, cardiovascular, or neurological condition contraindicating physical exercise; a history of significant injury in the last three months that could affect performance; current participation in any external structured resistance or athletic training program; and irregular school attendance likely to interfere with adherence to the intervention. During screening, 13 students were excluded: 6 due to recent injuries, 3 due to lack of parental consent, and 4 due to predicted dropout risk based on high absenteeism.

All 99 participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and were found eligible for inclusion. Baseline demographic information confirmed that participants were

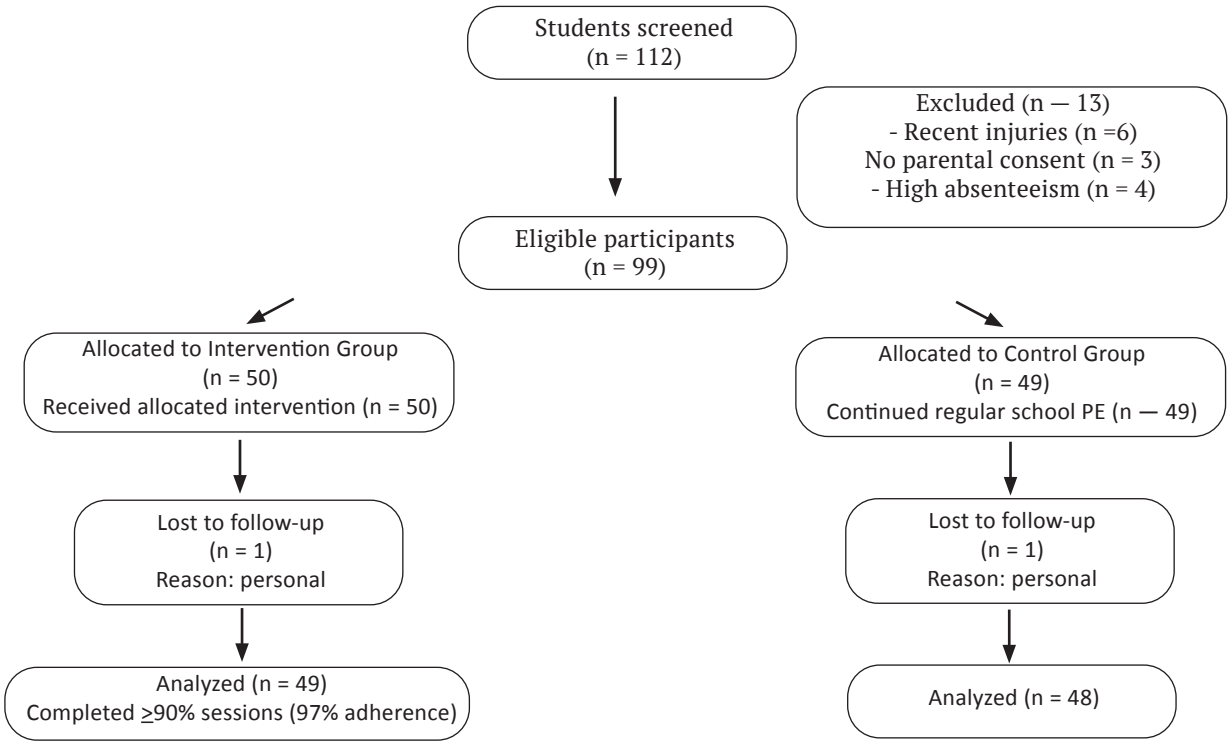

Figure 1. Participant Recruitment and Selection

comparable in age, gender distribution, and body mass index categories across groups. The research was organized in accordance with the recommendations for clinical research provided by the World Health Organization (WHO) within the Helsinki Declaration.

The resistance training program was delivered over 12 weeks in an after-school setting and followed a structured, progressive model. Training sessions were conducted three times per week on non-consecutive days and included bodyweight and circuit-based resistance exercises (squats, lunges, push-ups, planks, and plyometric jumps). Progression was systematically introduced by increasing sets, repetitions, and perceived exertion on a biweekly basis, with rest intervals adjusted accordingly. Exercise intensity was monitored using the Rating of Perceived Exertion (RPE, Borg scale 0–10), with participants encouraged to maintain proper technique before progressing in load or volume. Trainers ensured gradual overload while emphasizing safety and adherence. Table 2 provides the weekly breakdown of exercise prescription, including sets, repetitions, rest, intensity, and specific progression notes to enhance replicability. The overall design and progression strategy were consistent with recommendations for youth resistance training reported by Behringer et al. [47] and Stricker et al. [46].

The control group continued with their standard school-based physical education curriculum throughout the 12-week period. This curriculum consisted of two 40-minute sessions per week and included general calisthenics, aerobic games (e.g., relay races, football), and flexibility exercises. It did not include any structured resistance or strength training components. Attendance was monitored to ensure compliance with the control condition.

Outcome Measure

Anthropometry and Body Composition: Height (stadiometer) and weight (digital scale) were measured to compute BMI (kg/m^2). Skinfold thickness was taken at triceps and subscapular sites (calipers) to estimate body fat percentage. BMI was categorized as underweight, normal, overweight, or obese using CDC criteria. Together, these measures provided a health-related profile of participants.

Muscular Endurance: (1) Sit-ups: maximum number of bent-knee sit-ups in 30 seconds. (2) Push-ups: maximum number of standard push-ups in 30 seconds (for girls, modified knee push-ups). Both are reliable measures of core and upper-body endurance.

Muscular Power and Strength: (1) Standing Broad Jump: horizontal jump distance from a standing start, reflecting lower-body power. (2) Countermovement Jump (CMJ) Height: vertical jump measured with a jump mat or Vertec. (3) Medicine Ball Throw (seated): distance thrown with a 2-kg ball, assessing upper-body power (optional).

Aerobic Capacity: 6-Minute Run: distance covered in 6 minutes on an indoor track, estimating cardiorespiratory endurance.

Speed and Agility: 20-Meter Sprint: time to sprint 20 meters from a standing start (electronic timing if available).

Table 2. Intervention Protocol (Exercises: Squats, Lunges, Push-ups, Plank, Plyometric Jumps)

Week	Sets	Reps	Rest (sec)	Intensity (RPE)	Progression Notes
1	2	10–12	60	5–6	Familiarization, focus on technique
2	2	10–12	60	5–7	Maintain technique, gradual adaptation
3	3	12–15	60–75	6–7	Increase reps slightly each week
4	3	12–15	60–75	6–7	Add one extra set for main lifts
5	3	12–15	60–75	6–7	Introduce simple plyometric variations
6	3	12–15	60–75	6–7	Increase RPE to 6–7, ensure safe form
7	3–4	15–18	75–90	7–8	Progress reps and volume steadily
8	3–4	15–18	75–90	7–8	Introduce partner/bodyweight resistance
9	3–4	15–18	75–90	7–8	Add core circuit elements
10	3–4	15–18	75–90	7–8	Sustain 3–4 sets, RPE 7–8
11	4	18–20	90	8	Peak volume, close to 18–20 reps
12	4	18–20	90	8	Maintain intensity, prepare for post-test

Note. RPE = Rating of Perceived Exertion. Exercises remained constant throughout the program (squats, lunges, push-ups, plank, plyometric jumps).

Balance and Coordination: (1) Balance Backward: number of steps along a 6-m beam performed backward. (2) Lateral Jump: number of side-to-side jumps over a line in 15 seconds. (3) Rapid Alternating Foot Movement: number of taps across a line in 15 seconds. These tests are part of the EUROFIT battery and assess dynamic balance and coordination [51].

Flexibility: Sit-and-Reach: trunk flexion test, distance reached beyond toes. EUROFIT protocols were followed to ensure standardization. Scores from both legs or trials were averaged where appropriate.

All tests employed in this study are standardized field measures that have previously demonstrated acceptable validity and reliability in adolescent populations, particularly within the EUROFIT framework and related youth fitness protocols [51].

All training sessions were supervised by two certified strength and conditioning specialists (Master's in Physical Education, NSCA-CSCS certified). They completed a pre-intervention workshop to ensure standardized delivery. Fidelity was monitored using weekly checklists and attendance logs. Physical fitness assessments were conducted by blinded evaluators with postgraduate training. Inter-rater reliability was established during a pilot phase (ICC > 0.90). Data entry and analysis were performed using anonymized codes to minimize bias. Participants were unaware of group allocation until study completion. Trainers had no role in data analysis, thereby reducing expectancy and confirmation bias.

Statistical Analysis

All analyses were performed using SPSS, version 26 (IBM Corp., Armonk, NY, USA). The assumption of normality was verified for each variable using the Shapiro–Wilk test. Descriptive statistics are presented as mean ± standard deviation (SD). To examine the intervention effects, a 2×2 mixed-model MANOVA was conducted with Group (Intervention vs. Control) as the between-subjects factor and Time (pre-test vs. post-test) as the within-subjects factor. When significant Group × Time interactions were observed, follow-up analyses included mixed-model ANOVAs for each outcome variable, as well as paired-sample t-tests to identify within-group changes. Effect sizes were reported as partial eta squared (η^2) for ANOVA models and as Cohen's d for paired comparisons. Bonferroni adjustments were applied within fitness domains to control for multiple comparisons. Statistical significance was set at $\alpha = 0.05$.

Results

A total of 99 adolescents completed the study, with high adherence observed in the intervention group (97%). Two participants, one from each group, withdrew due to personal reasons unrelated to the intervention. Baseline analyses confirmed that the intervention and control groups were comparable in age, gender distribution, and fitness status. Over the 12 weeks, the intervention group demonstrated clear improvements in multiple domains of physical fitness, while the control group showed minimal or no changes.

Mean performance values (± SD) across all fitness tests at baseline and post-intervention for IG and CG are presented in Table 3. The IG demonstrated marked improvements in sit-ups, push-ups, broad jump, countermovement jump, sprint, and aerobic capacity, whereas CG showed negligible changes.

In Table 3, the intervention group demonstrated clear improvements in muscular endurance (sit-ups, push-ups), power (broad jump, countermovement jump), speed (20-m sprint), aerobic capacity (6-min run), and coordination (lateral jumps). Balance

showed only minor gains, while flexibility (sit-and-reach) and BMI remained largely unchanged in both groups, suggesting that these parameters were not sensitive to the 12-week training period.

Table 4 reports the inferential statistics for Group × Time interactions across fitness variables. Large effects were observed for muscular endurance (sit-ups, push-ups) and power (broad jump, CMJ).

In Table 4, significant improvements were also found in sprint performance, aerobic capacity, and motor coordination (lateral jumps, balance). Non-significant outcomes for flexibility and BMI confirm that the intervention produced domain-specific effects rather than generalized changes across all parameters.

The improvements observed in muscular strength, endurance, speed, and coordination highlight not only physical fitness gains but also outcomes relevant to recreational and rehabilitative practice. Enhanced balance, motor control, and aerobic capacity suggest that such programs may contribute to recovery from sedentary routines, reduction of school-related stress, and the development of resilience in adolescents. The absence of adverse changes in BMI and flexibility further indicates the safety of implementing resistance-based recreation as a health-oriented practice in school environments.

Table 5 presents within-group pre–post comparisons for IG participants. Large to very large improvements were seen in sit-ups (d = 1.20), push-ups (d = 1.07), broad jump (d = 1.35), and sprint (d = 0.85).

Moderate improvements were observed in CMJ, the 6-min run, lateral jumps, and balance. Flexibility and BMI showed no significant changes, reinforcing the specificity of resistance training adaptations.

The intervention group showed large improvements in muscular endurance (sit-ups, push-ups), muscular power (broad jump,

Table 3. Pre- and post-intervention performance

Measure	Intervention Pre	Intervention Post	Control Pre	Control Post
Sit-ups (reps/30s)	28.4 ± 7.2	37.5 ± 8.1 **	27.9 ± 6.8	28.7 ± 7.0
Push-ups (reps/30s)	22.1 ± 5.4	28.3 ± 6.2 **	22.3 ± 5.6	23.0 ± 5.7
Broad Jump (cm)	190.5 ± 15.8	213.1 ± 18.4 **	191.2 ± 16.2	192.4 ± 16.0
Countermovement Jump Height (cm)	29.4 ± 4.5	31.9 ± 4.8 **	29.7 ± 4.2	30.0 ± 4.4
20-m Sprint (s)	3.72 ± 0.18	3.54 ± 0.15 **	3.70 ± 0.19	3.68 ± 0.20
6-min Run (m)	1260 ± 85	1338 ± 92 *	1255 ± 80	1259 ± 84
Lateral Jumps (n/15s)	47.0 ± 5.5	50.8 ± 5.9 **	46.5 ± 5.2	47.1 ± 5.3
Flexibility (Sit-and-Reach, cm)	30.0 ± 4.0	31.5 ± 3.5	29.8 ± 4.1	30.5 ± 3.7
Body Composition (BMI, kg/m²)	19.8 ± 2.5	19.7 ± 2.4	20.1 ± 2.6	20.0 ± 2.5
Balance and Coordination (Backward Steps, n)	7.0 ± 2.5	7.3 ± 2.4	6.8 ± 2.7	7.0 ± 2.5

Note. Values are mean ± SD. *p < 0.05; **p < 0.01, within-group changes in the Intervention group (paired t-test). Group × Time ANOVA interactions were significant for all starred measures.

Table 4. Summary of Repeated Measures ANOVA Results (Group × Time Interaction)

Fitness Measure	F(1,95)	p-value	Partial η²
Sit-ups (reps/30s)	28.4	<0.001	0.23
Push-ups (reps/30s)	22.1	<0.001	0.19
Broad Jump (cm)	34.7	<0.001	0.26
CMJ Height (cm)	12.8	0.001	0.12
6-min Run (m)	4.2	0.044	0.04
20-m Sprint (s)	15.6	<0.001	0.14
Lateral Jumps (15s)	7.3	0.008	0.07
Balance – Backward Steps	4.1	0.045	0.04
Flexibility – Sit-and-Reach (cm)	0.34	0.56	0.01
Body Composition – BMI (kg/m²)	0.15	0.70	0.00

Note. Bold values indicate statistically significant interactions at p < 0.05. Partial eta squared (η^2): ⩾ 0.14 = large, ⩾ 0.06 = medium, ⩾ 0.01 = small. CMJ = countermovement jump.

Table 5. Within-Group Paired t-test Summary for the Intervention Group (n = 50)

Measure	Pre (Mean ± SD)	Post (Mean ± SD)	t(49)	p-value	Cohen's d
Sit-ups (reps/30s)	28.4 ± 7.2	37.5 ± 8.1	9.21	<0.001	1.20
Push-ups (reps/30s)	22.1 ± 5.4	28.3 ± 6.2	8.73	<0.001	1.07
Broad Jump (cm)	190.5 ± 15.8	213.1 ± 18.4	10.11	<0.001	1.35
CMJ Height (cm)	29.4 ± 4.5	31.9 ± 4.8	4.72	<0.001	0.68
6-min Run (m)	1260 ± 85	1338 ± 92	2.22	0.03	0.32
20-m Sprint (s)	3.72 ± 0.18	3.54 ± 0.15	6.11	<0.001	0.85
Lateral Jumps (n/15s)	47.0 ± 5.5	50.8 ± 5.9	3.98	<0.001	0.56
Balance (Backward Steps, n)	7.0 ± 2.5	7.3 ± 2.4	2.05	0.045	0.29
Flexibility (Sit-and-Reach, cm)	30.0 ± 4.0	31.5 ± 3.5	1.81	0.075	0.25
BMI (kg/m^2)	19.8 ± 2.5	19.7 ± 2.4	0.56	0.58	0.08

countermovement jump), and speed (20-m sprint). Moderate improvements were also observed in aerobic capacity (6-min run), balance, and coordination (lateral jumps). Flexibility and BMI did not change significantly. In contrast, the control group showed minimal or no changes across fitness measures.

These within-group gains demonstrate that structured resistance training can be safely applied as a form of recreational activity that promotes functional recovery, supports resilience, and enhances overall well-being in adolescents. The improvements in balance, coordination, and aerobic performance are particularly relevant from a rehabilitative perspective, as they reflect adaptations that help counteract sedentary behavior and reduce vulnerability to health risks in adolescents.

Discussion

The aim of this study was to evaluate the effects of a 12-week structured resistance training program on physical fitness and its broader recreational and rehabilitative relevance for adolescents aged 13–16 years. The intervention group demonstrated clear improvements in muscular endurance, power, speed, aerobic capacity, and coordination compared to the control group, while flexibility and BMI remained unchanged. These findings indicate that a school-based resistance training program can selectively enhance multiple domains of physical fitness in adolescents and, at the same time, function as a recreational format that supports recovery, resilience, and long-term health in educational settings.

This study demonstrates that a 12-week after-school resistance training program can substantially improve physical fitness in Indian adolescents. While numerous studies across Europe and North America have established the effectiveness of youth resistance training in enhancing muscular strength, power, and coordination [4, 47, 50], evidence from South Asian contexts remains scarce. To our knowledge, few investigations have examined structured resistance training among Indian adolescents, particularly within low-resource public-school environments, where the recreational and rehabilitative potential of such programs is especially relevant.

The novelty of the present study lies not in the training model itself, which builds upon established international protocols such as EUROFIT, but in its contextual application. Specifically, this research demonstrates the feasibility of implementing a structured after-school resistance training program among Indian adolescents of both genders, showing how such interventions can be adapted within resource-constrained educational settings. By documenting outcomes across multiple domains of physical fitness, the study contributes pedagogical insights relevant to school-based health promotion in India, while also emphasizing the recreational and rehabilitative value of resistance training as a means to counter sedentary routines, reduce stress, and support adolescent resilience. Thus, rather than methodological innovation, the contribution of this work is situated in addressing an underrepresented demographic, validating global recommendations in a novel setting, and offering practical evidence for integrating resistance training into physical education as a recreational and rehabilitative strategy.

The intervention group showed marked gains in muscular endurance, strength, and power, whereas the control group exhibited no comparable changes. These findings corroborate previous work, with Kretschmann [4] reporting strength gains after 8 weeks in German youth and Velez et al. [50] observing similar improvements in Hispanic adolescents. Together, these studies and our results highlight the cross-cultural validity of resistance training as a scalable intervention. Our findings also extend Indian evidence of low adolescent fitness [5, 20], underscoring the need for structured programs.

Aerobic capacity showed modest improvement,

suggesting indirect benefits through better muscle efficiency. This outcome is consistent with findings in adolescent rugby players [52]. Flexibility and BMI remained unchanged, which is expected for a short, strength-focused program. These results align with meta-analytic evidence on progressive strength gains [47] and international guidelines promoting youth resistance exercise [46, 48]. No injuries occurred, supporting the safety of supervised training [35].

Overall, the observed improvements have practical value. Stronger adolescents can more effectively participate in daily activities and sports, while also counteracting health risks associated with poor fitness, inactivity, and obesity [9, 15, 18, 20]. In addition, the gains in balance, coordination, and aerobic performance highlight outcomes that are relevant to recreational and rehabilitative practice, as they contribute to recovery from sedentary routines, reduction of school-related stress, and promotion of resilience in adolescents. These results support the view that structured resistance training can serve not only as a method of fitness enhancement but also as a health-oriented approach integrated into recreational and rehabilitative frameworks.

By extending the program to 12 weeks, participants achieved large effect sizes in core endurance and upper-body strength, with sit-ups and push-ups showing improvements of approximately 32% and 28% (Cohen's d ≈ 1.1–1.2). These outcomes are consistent with meta-analytic findings that strength gains in adolescents increase with longer training periods [47]. The results also align with international recommendations that youth engage in muscle-strengthening activity at least three times per week [46, 48]. The program was well-tolerated and safe: no injuries occurred, supporting the view that supervised, age-appropriate resistance training poses minimal risk [35].

Performance gains extended across several domains. Improvements in jump distance (+12%) and sprint time (−5%) indicate enhanced lower-body power and neuromuscular function, while modest increases in the 6-minute run (+6%) suggest secondary aerobic benefits. Balance and coordination also improved slightly, demonstrating transfer to general motor skills. In contrast, flexibility remained unchanged, which is expected given that it was not a target of the regimen. BMI and skinfold measures likewise showed no significant changes, consistent with evidence that meaningful alterations in body composition require longer training periods, higher intensities, or dietary modification [26]. Importantly, maintenance of BMI alongside possible gains in lean mass (not directly measured here) may still reflect positive health adaptations.

These findings have practical implications. Stronger and more powerful adolescents are better equipped to participate in sports and daily activities, and may benefit from increased self-efficacy and confidence [46]. The school-based format addresses common barriers to adolescent fitness in India, including limited access to safe exercise environments, and provides a feasible pathway for integrating structured resistance training into public education.

In addition to these physiological outcomes, the observed improvements carry clear recreational and rehabilitative significance. Gains in endurance, power, and coordination contribute to restoring functional capacity, reducing the negative impact of sedentary school routines, and supporting stress recovery in adolescents. The safe and feasible school-based design also highlights the potential of such programs to be integrated as part of recreational and rehabilitative strategies aimed at sustaining health and resilience in adolescents.

Previous research supports these conclusions. A 12-week resistance program produced significant strength gains in exercises such as bench press, seated row, shoulder press, and squats [50]. Improvements in cardiorespiratory fitness have been reported through Shuttle Run Test and VO_2max [53], while other studies document benefits in agility, flexibility, and repetitive strength [54]. Moreover, resistance training has been linked to reductions in cardiovascular risk factors, including triglycerides, LDL, blood glucose, and systolic blood pressure, alongside decreases in body fat and increases in lean mass [55]. Beyond physical outcomes, positive effects on self-concept, competence, and global self-worth have also been demonstrated [50].

Resistance training has been shown to significantly increase muscular strength in adolescents, with documented improvements in bench press, seated row, shoulder press, and squats [50]. Functional strength training also produced gains in curl-ups and pull-ups, reflecting enhanced muscular endurance [56]. Increases in lower-body strength have been associated with better sprint performance, particularly in rugby players [52], and improved jump performance further highlights adaptations in muscular power [52]. Functional movement quality, including balance and coordination, has also improved under resistance training, as evidenced by higher scores in the Functional Movement Screen protocol [56]. While the benefits are clear, program design and supervision remain critical to ensure safety and maximize effectiveness. Collectively, these positive outcomes underscore the role of resistance training as a valuable component of physical education curricula, supporting the development of lifelong fitness habits among adolescents [57].

In addition to supporting physical education, resistance training can be viewed as a recreational and rehabilitative approach that helps adolescents recover from sedentary routines and academic

stress while strengthening their overall functional capacity. The documented improvements in endurance, coordination, and movement quality indicate that such programs not only enhance fitness but also promote resilience, psychological well-being, and long-term health maintenance in adolescents. This dual role underscores the potential of resistance training to serve simultaneously as an educational strategy and a practical tool for recreation- and rehabilitation-oriented practice in school settings.

A study showed that participation in structured exercise programs improved adolescents' quality of life and physical well-being, while fostering a positive attitude toward physical activity [54]. Putera [58] reported that plyometric training, including countermovement jumps (CMJ), significantly enhanced strength and power in adolescent students, supporting the effectiveness of explosive lower-body training. Our findings also align with Kumar et al. [59], who observed that obese children demonstrated reduced competence in object control and rolling/turning tasks, suggesting that excess weight can limit motor skill acquisition. Recent evidence further indicates that integrated training methods combining core and plyometric exercises improve agility, balance, and sport-specific skills in youth tennis players [50, 56, 60]. These converging results support the scalability of our model and challenge misconceptions that Indian adolescents are inherently weak or that resistance training should be restricted to athletes. Our findings are consistent with recent evidence showing that integrated training methods combining core and plyometric exercises significantly enhance agility, dynamic balance, and sport-specific skills in young tennis players [61].

Taken together, these findings emphasize that structured training formats can provide adolescents not only with measurable improvements in strength, agility, and coordination but also with recreational opportunities that promote recovery, reduce stress, and support psychosocial well-being. By integrating resistance and functional exercises into school settings, such programs can be positioned as rehabilitative practices that counteract the negative effects of sedentary lifestyles and academic load, thereby contributing to the holistic development and resilience of adolescents.

Pedagogical, Recreational, and Rehabilitative Relevance

Beyond physiological adaptations, this study highlights clear educational, recreational, and rehabilitative benefits. Gains in muscular endurance, power, and coordination directly support physical literacy, which is a central goal of school physical education. At the same time, structured after-school resistance programs function as a form of health-oriented recreation, providing adolescents with opportunities to reduce stress, restore energy, and enhance psychological well-being. Improved fitness gives students the confidence and competence to engage in lifelong physical activity, while the recreational format fosters psychosocial outcomes such as self-efficacy, resilience, and peer engagement. The program's reliance on minimal equipment (bodyweight, resistance bands, medicine balls) and its emphasis on close supervision ensure feasibility in low-resource schools. Taken together, resistance training can be regarded not only as a fitness strategy but also as a pedagogical and rehabilitative model for integrating health-oriented practices into education. The results contribute context-specific evidence from Indian adolescents and highlight the broader integration of resistance training into school-based physical education, recreation, and rehabilitation activities.

Limitations

This study used a quasi-experimental design with intact class allocation, which may introduce selection bias despite baseline equivalence. The sample was limited to urban schools, and the intervention lasted only 12 weeks, which restricts the ability to evaluate longer-term adaptations. In addition, outcomes directly related to recreation and rehabilitation, such as indicators of recovery, stress reduction, and quality of life, were not measured, limiting the scope of conclusions about the broader health-oriented effects of the program.

Future Research Directions

Future studies should explore the role of structured resistance training as a component of recreational and rehabilitative practice. Particular attention should be paid to long-term outcomes, including sustained recovery, resilience, and maintenance of health-related quality of life. Expanding research to diverse adolescent populations and different educational environments will strengthen evidence on how such programs can be applied as practical tools for recreation and rehabilitation in school settings.

Conclusions

Structured resistance training demonstrates strong potential as a school-based strategy for promoting adolescent health, recreation, and educational development. Beyond its physiological effects, such programs enhance motor competence, confidence, and long-term engagement in physical activity. Implemented in supportive school environments, resistance training enriches physical education by combining fitness enhancement with pedagogical value and by creating opportunities for recovery and stress reduction. The findings suggest that school-based resistance training can serve as a practical model of recreational and rehabilitative

practice, contributing to sustained health, working capacity, and holistic well-being of adolescents.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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ORIGINAL ARTICLE

Comparative study of emotional intelligence and mental toughness across age and gender in Eastern Zone chess players

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Abstract

Background and Study Aim: Psychological traits such as Emotional Intelligence (EI) and Mental Toughness (MT) are increasingly recognized as performance determinants in cognitively demanding sports like chess. These traits influence how players cope with pressure, maintain focus, and sustain consistency during competitions. Although both EI and MT are applied in the context of cognitive sports, their relative effectiveness in enhancing performance remains a matter of practical interest. The aim of this study was to assess and compare EI and MT among national-level chess players from North-East India across gender and age categories.

Material and Methods: A total of 106 national-level chess players (males = 58; females = 48), aged 18–25 years, voluntarily participated in the study. Emotional intelligence and mental toughness were assessed using standardized questionnaires with established reliability (α = 0.88; KR-20 = 0.86). Data were collected in person during training camps and tournaments. The Shapiro–Wilk test was used to verify data normality. Depending on distribution, parametric (t-test, ANOVA) and non-parametric (Mann–Whitney U, Kruskal–Wallis H) tests were applied. Correlation analysis was performed using Spearman's rank-order coefficient, with statistical significance set at $p < .05$.

Results: Female players reported significantly higher emotional intelligence than males ($p = .023$, $d = 0.45$). No significant gender difference was found in overall mental toughness ($p > .05$). Age groups showed no difference in emotional intelligence ($p = .169$), but older players demonstrated higher scores in specific mental toughness components, particularly rebound ability and motivation ($p < .05$). A moderate positive correlation was observed between emotional intelligence and overall mental toughness ($r = 0.52$, $p < .001$).

Conclusions: The study highlights the relevance of psychological characteristics such as emotional intelligence and mental toughness in chess. The findings may help in designing targeted psychological preparation and support strategies for athletes engaged in cognitively demanding sports.

Keywords: emotional intelligence, mental toughness, ability to handle pressure, rebound-ability, chess, psychological skills.

Introduction

Chess is widely regarded as a cognitively demanding sport that requires sustained concentration, strategic planning, and emotional regulation. Performance in such a setting is shaped not only by technical skills and knowledge of the game but also by psychological resources that enable players to cope with stress, manage setbacks, and maintain consistency under competitive pressure. Among these resources, Emotional Intelligence (EI) and Mental Toughness (MT) have gained attention for their potential to influence motivation, resilience, and decision-making. They are therefore regarded as factors of interest when examining success in cognitive sports. Within the broader framework of physical culture, these mental attributes are essential for maintaining psychological balance, promoting adaptive functioning, and supporting health through recreation and mental training. Chess, although non-physical in nature, shares the aims of physical culture and rehabilitation by fostering self-control, stress tolerance, and emotional stability, which are key components of holistic human development.

Building on this perspective, EI refers to the ability to perceive, understand, and manage one's own and others' emotions [1]. In sports, emotionally intelligent athletes can regulate their emotional responses effectively [2]. MT, in turn, reflects the capacity to cope with pressure, adversity, and stress without giving up. It encompasses confidence, constancy, control, and resilience [3]. An athlete's success depends not only on physical abilities but also on a strong mental structure [4]. Thus, in a cognitively demanding sport like chess, these psychological constructs are likely integral to peak performance.

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In the context of chess, an elite cognitive sport, both EI and MT appear especially relevant. Players must make complex strategic decisions under time pressure while managing the emotional highs of victory and the lows of defeat. Although specific studies on EI and MT in chess are limited, related research illustrates their role. One study [5] found that Turkish chess players scored high on a mental endurance inventory, and this "mental endurance" strongly predicted their psychological well-being. The authors noted that "having mental ability does not mean mental toughness," emphasizing that resilience must be developed separately. In other sports contexts, researchers [6] likewise observed that elite success depends on both physical and psychological strengths. By analogy, chess players with high EI and MT may be better at sustaining focus, handling stress, and maintaining composure in critical positions. These traits can help players avoid emotional swings (e.g., frustration after a mistake) and make more consistently sound moves.

Demographic factors such as age and gender also influence EI and MT, but findings are mixed. Some studies suggest these skills develop with experience, while others show no clear trend. For example, researchers [6] compared young athletes (aged 12–18) and observed that younger adolescents (12–15 years) scored higher on EI measures than older teens. In contrast, another study [7] found that older male athletes (26–33 years) had higher mental endurance and EI scores than their younger counterparts. Gender differences are likewise inconsistent. Female student-athletes scored higher than males on the confidence and constancy dimensions of MT, as well as on overall MT [8]. Related findings indicate that female athletes often exhibit superior emotional regulation and consistency under pressure [9]. Conversely, one study [10] reported higher EI scores among young male athletes than among females. These mixed results suggest that age and gender may shape psychological skills in complex ways, possibly interacting with cultural or sport-specific factors. In chess, for instance, maturation may enhance emotion regulation, while gender norms could influence confidence levels or emotional expression. Emotional intelligence and mental toughness are well-established determinants of athletic success [11], yet their specific roles in chess and their modulation by demographic factors are not well understood. In this context, demographic patterns in psychological traits may provide "strategic recommendations" for optimizing performance [11].

Analysis of research findings has shown that emotional intelligence and mental toughness contribute to athletic performance, including in cognitive competitions like chess. Researchers emphasize the practical importance of demographic context, as age and gender can shape these psychological constructs. At the same time, chess and specific populations remain insufficiently characterized with respect to psychological profiles. This includes the culturally distinct Eastern Zone states of India, which have produced competitive chess talent. Nevertheless, there remains a need for further research. This gap continues to hinder a comprehensive analysis of how psychological factors operate within the context of competitive chess. The aim of this study was to assess and compare EI and MT among national-level chess players from North-East India across gender and age categories.

Materials and Methods

Participants

A total of 106 national-level chess players (males = 58; females = 48), aged 18–25 years, voluntarily participated in the study. The participants were purposively selected from various states in North-East India, including Assam, Manipur, Mizoram, Tripura, and Arunachal Pradesh. All had represented their respective states in official national-level chess tournaments recognized by the national sports federation. For comparative analysis, participants were divided into two age-based groups: 18–21 years (n = 54) and 22–25 years (n = 52). Gender-based comparisons were also conducted to examine potential psychological differences between male and female chess players.

All participants were informed about the study objectives, assured of the confidentiality and anonymity of their responses, and reminded that participation was voluntary. Written informed consent was obtained from each participant before data collection began. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki and approved by the institutional ethics committee.

Study Design

Emotional Intelligence Scale

Emotional intelligence was assessed using the standardized *Emotional Intelligence Scale* developed by Dr. Nicola Schutte et al. [12]. The scale is based on the theoretical model proposed by Mayer and Salovey [13] and comprises 33 self-report items rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). It measures an individual's ability to perceive, understand, regulate, and utilize emotions effectively in both personal and interpersonal contexts. The total score is obtained by summing all item responses, with higher scores indicating higher emotional intelligence. The reliability coefficient (Cronbach's alpha) for the present study sample was 0.88, demonstrating a high level of internal consistency.

Mental Toughness Questionnaire

Mental toughness was measured using the

Mental Toughness Questionnaire developed by Dr. Alan Goldberg [14]. This questionnaire consists of 30 items with dichotomous (true/false) response options. It is structured around five subscales, each containing six items: Rebound Ability, Ability to Handle Pressure, Concentration, Confidence, and Motivation. Each item was scored as 1 if the response matched the validated scoring key and 0 otherwise, yielding subscale scores ranging from 0 to 6. A higher subscale score indicates greater strength in that particular domain of mental toughness. The overall mental toughness score was obtained by summing the scores from all five subscales, producing a maximum possible total of 30. Internal consistency for each subscale and for the total score was assessed using the Kuder–Richardson Formula 20 (KR-20), a reliability measure suitable for dichotomous items, frequently applied in studies related to sport and physical culture [15, 16]. The internal consistency coefficients for the five subscales ranged from 0.70 to 0.84, confirming satisfactory reliability.

Data collection was conducted in person at training camps, tournament venues, and institutional sports facilities where the participants were available. The questionnaires were administered in a paper-based format in a controlled and distraction-free setting. Standardized instructions were provided both verbally and in writing to ensure consistent understanding of the items. Participants were instructed to answer the items independently. They were encouraged to seek clarification only for comprehension-related queries, not for the item content. Each administration session lasted approximately 25 to 30 minutes. All completed responses were carefully screened for completeness before inclusion in the final dataset. No compensation or incentives were provided to participants, and the confidentiality of individual responses was strictly maintained throughout the study.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics software, version 26. Descriptive statistics, including means, standard deviations, minimum and maximum scores, and internal consistency estimates, were computed for both emotional intelligence and mental toughness variables. The internal consistency of the Emotional Intelligence Scale was assessed using Cronbach's alpha, while the reliability of the dichotomously scored MTQ was evaluated using the Kuder–Richardson Formula 20. The Shapiro–Wilk test was employed to examine the normality of score distributions for each variable.

Since the Emotional Intelligence scores followed a normal distribution, parametric tests were applied for inferential comparisons. Independent samples t-tests were used to examine gender-based differences, and one-way analysis of variance (ANOVA) was used to compare emotional intelligence across age groups. In contrast, the Mental Toughness total and subscale scores did not meet the assumption of normality. Therefore, non-parametric statistical techniques were employed. The Mann–Whitney U test was used to analyze gender differences, and the Kruskal–Wallis H test was used to examine age group differences in the five subdomains of mental toughness.

Spearman's rank-order correlation coefficient was computed to determine the strength and direction of associations between emotional intelligence and overall mental toughness, as well as with each mental toughness subscale. A significance level of $p < .05$ was maintained throughout the analysis.

Results

Table 1 presents the descriptive statistics and reliability coefficients for emotional intelligence and the five subdomains of mental toughness. The table includes the number of participants, means, standard deviations, minimum and maximum values, and reliability estimates for each variable.

Table 1 summarizes the descriptive statistics for EI and the five MT subdomains, along with internal consistency estimates. The mean EI score was 131.62 ± 10.24. MT subscale scores ranged from 0 to 6, with the highest mean observed for Motivation (4.63 ± 0.97). Reliability analysis showed good internal consistency for all variables. Cronbach's alpha for the EI scale was 0.88, and KR-20 coefficients for the MT subscales ranged from 0.70 (Motivation) to 0.84 (Concentration), indicating acceptable reliability.

Table 2 presents the results of the Shapiro–Wilk test used to examine the normality of data distribution for emotional intelligence and mental

Table 1. Descriptive Statistics and Reliability of Emotional Intelligence and Mental Toughness Subscales

Variable	N	Mean	SD	Min	Max	Reliability
Emotional Intelligence (EI)	106	131.62	10.24	107	153	α = 0.88
Rebound Ability	106	4.51	1.02	2	6	KR-20 = 0.82
Ability to Handle Pressure	106	4.42	1.13	1	6	KR-20 = 0.78
Concentration	106	4.36	1.21	1	6	KR-20 = 0.84
Confidence	106	4.48	1.08	2	6	KR-20 = 0.79
Motivation	106	4.63	0.97	3	6	KR-20 = 0.70

toughness variables. The table shows that emotional intelligence scores met the assumption of normality, whereas all subscales of mental toughness did not.

As shown in Table 2, emotional intelligence followed a normal distribution, while all subdomains of mental toughness exhibited non-normal distributions. These findings justified the use of parametric tests for emotional intelligence and non-parametric procedures for mental toughness in subsequent analyses.

Table 3 presents the comparison of emotional intelligence and mental toughness scores between male and female chess players. Parametric and non-parametric tests were applied according to data distribution to identify potential gender-related differences across all measured variables.

Table 2. Shapiro–Wilk Test for Normality

Variable	W Statistic	p-value	Interpretation
Emotional Intelligence	0.991	0.677	Normally distributed
Rebound Ability	0.958	0.005	Not normally distributed
Handle Pressure	0.951	0.003	Not normally distributed
Concentration	0.947	0.001	Not normally distributed
Confidence	0.954	0.004	Not normally distributed
Motivation	0.945	0.002	Not normally distributed

Table 3. Gender Differences in Emotional Intelligence and Mental Toughness Subscales

Variable	Gender	Mean / Median (SD)	Test	p-value	Effect Size
Emotional Intelligence	Male	129.74 ± 10.52	t (104) = -2.31	0.023*	d = 0.45
	Female	133.61 ± 9.53			
Rebound Ability	Male	Mdn = 4	U = 1208.5	0.089	r = 0.17
	Female	Mdn = 5			
Handle Pressure	Male	Mdn = 4	U = 1185.0	0.076	r = 0.18
	Female	Mdn = 5			
Concentration	Male	Mdn = 4	U = 1156.0	0.062	r = 0.19
	Female	Mdn = 5			
Confidence	Male	Mdn = 5	U = 1250.0	0.112	r = 0.15
	Female	Mdn = 5			
Motivation	Male	Mdn = 4	U = 1238.5	0.101	r = 0.16
	Female	Mdn = 5			

*Significant at p < .05

Table 3. Gender Differences in Emotional Intelligence and Mental Toughness Subscales

Variable	Gender	Mean / Median (SD)	Test	p-value	Effect Size
Emotional Intelligence	Male	129.74 ± 10.52	t (104) = -2.31	0.023*	d = 0.45
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Rebound Ability	Male	Mdn = 4	U = 1208.5	0.089	r = 0.17
	Female	Mdn = 5			
Handle Pressure	Male	Mdn = 4	U = 1185.0	0.076	r = 0.18
	Female	Mdn = 5			
Concentration	Male	Mdn = 4	U = 1156.0	0.062	r = 0.19
	Female	Mdn = 5			
Confidence	Male	Mdn = 5	U = 1250.0	0.112	r = 0.15
	Female	Mdn = 5			
Motivation	Male	Mdn = 4	U = 1238.5	0.101	r = 0.16
	Female	Mdn = 5			

*Significant at p < .05

Table 4. Age Group Differences in Emotional Intelligence and MT Subscales

Variable	Age Group	Mean / Median	Test	p-value	Effect Size
Emotional Intelligence	18–21	130.45 ± 10.81	F (1,104) = 1.92	0.169	$\eta^2 = 0.02$
	22–25	132.75 ± 9.52			
Rebound Ability	18–21	Mdn = 4	U = 1032.5	0.015*	r ≈ 0.26
	22–25	Mdn = 5			
Motivation	18–21	Mdn = 4	U = 1068.0	0.021*	r ≈ 0.24
	22–25	Mdn = 5			
Other Subscales	—	—	—	> 0.05	ns

*Significant at $p < .05$

Table 5. Correlations Between Emotional Intelligence and MT Subscales

MT Subscale	Spearman's ρ	p-value
Rebound Ability	0.348	0.004*
Handle Pressure	0.421	< .001*
Concentration	0.467	< .001*
Confidence	0.336	0.006*
Motivation	0.389	0.002*
Total MT Score	0.508	< .001*

*Significant at $p < .05$

As shown in Table 3, female players demonstrated higher emotional intelligence scores than males, with a moderate effect size. Differences across mental toughness subscales were not statistically significant, although females tended to show slightly higher median values in several domains, particularly in concentration and the ability to handle pressure.

Table 4 presents the comparison of emotional intelligence and mental toughness scores between the two age groups of chess players. Parametric and non-parametric tests were applied depending on the data distribution to identify potential age-related variations across the studied variables.

As shown in Table 4, emotional intelligence did not differ significantly between younger and older chess players. However, older players showed higher levels of mental toughness in specific domains, particularly in rebound ability and motivation. No significant differences were observed in the remaining subscales of mental toughness.

Table 5 presents the correlation coefficients between emotional intelligence and the subscales of mental toughness. Spearman's rank-order correlations were computed to examine the strength and direction of associations between these variables.

As shown in Table 5, emotional intelligence demonstrated a positive association with overall mental toughness. Similar positive relationships were observed across all subdomains, with stronger correlations evident for concentration, the ability to handle pressure, and motivation.

Overall, the results showed that emotional intelligence was normally distributed, whereas most mental toughness indicators were not. Female players exhibited higher emotional intelligence, while age-related differences were mainly reflected in specific aspects of mental toughness, such as rebound ability and motivation. Positive associations were observed between emotional intelligence and all components of mental toughness, indicating that greater emotional competence was related to higher psychological resilience in chess players.

Discussion

The main aim of this study was to assess and compare emotional intelligence and mental toughness among national-level chess players from North-East India across gender and age categories. The findings showed that female players demonstrated higher emotional intelligence than males, whereas gender differences in mental toughness were not significant. Age did not affect emotional intelligence but was related to certain aspects of mental toughness, with older players showing greater rebound ability and motivation. A moderate positive association was also observed between emotional intelligence and overall mental toughness.

Prior research indicates that individuals engaged in chess exhibit heightened emotional regulation and cognitive control, both essential for superior performance [17]. These attributes align with the demands of the sport, including sustained focus, error avoidance, and resilience under psychological

stress [18]. The higher emotional intelligence often observed in female players can be explained through gender-linked patterns of emotional processing. Women typically demonstrate stronger emotion perception and regulation [19], which in chess may translate into more effective handling of competitive stress and strategic emotional management. Emotional awareness supports decision-making under pressure, as suggested by previous findings [20], and may facilitate adaptive responses to adversity and anticipation of opponents' behaviour.

The development of mental toughness is influenced by experience and age. As individuals progress through competitive stages, they gain exposure to high-pressure situations and setbacks, which fosters greater psychological resilience [21]. Chess players, in particular, benefit from repeated exposure to tournament tension, mistakes, and shifting momentum, all of which contribute to stronger coping strategies. The subdomains of concentration and rebound ability are especially cultivated due to the extended duration and high cognitive load of chess games [22]. The observed positive relationship between emotional intelligence and mental toughness is consistent with theoretical propositions suggesting that emotional control enhances cognitive resilience [23]. In chess, players with stronger emotional regulation are better equipped to handle pressure, maintain concentration, and recover from mistakes [24]. Emotional competence therefore appears to strengthen mental toughness by promoting adaptive stress responses and attentional control.

From the perspective of physical culture and rehabilitation, these psychological mechanisms reflect broader processes of self-regulation and stress management that contribute to maintaining mental well-being and functional balance. Developing emotional control and resilience through cognitive sports like chess can thus complement recreational and educational programs aimed at fostering holistic health and adaptive behaviour.

Furthermore, mental toughness, encompassing consistency and psychological stamina, is integral to chess performance. Tournament preparedness, characterized by strategy, emotional regulation, and endurance across multiple rounds, reflects this trait [25]. The development of such mental habits aligns with broader psychological models, including the Individual Zone of Optimal Functioning [13, 24], which emphasizes individualized emotional control strategies. Skill progression in chess is also intertwined with psychological growth. Greater concentration, pressure control, and motivational resilience not only represent behavioural adaptation but also cognitive maturation, contributing to strategic depth and pattern recognition [12]. The integrated model of emotional intelligence and mental toughness suggests that emotional regulation enhances focus and reduces reactivity to errors, while mental toughness supports recovery and sustained effort during prolonged games.

Interventions aimed at improving mindfulness and preparation for competitive pressure, which are widely applied in physical sports, are also gaining empirical support in chess [26]. Approaches such as mental rehearsal, emotion regulation strategies, and cognitive behavioural techniques have been shown to enhance both emotional intelligence and mental toughness [27]. These findings support the recommendation that psychological skill training should be integrated into chess coaching, extending beyond purely technical or tactical instruction. In addition, combining quantitative assessments with psychophysiological indicators such as heart rate variability, cortisol levels, and eye tracking during gameplay can provide deeper insight into stress reactivity and emotional cognitive regulation. This multi method approach offers greater ecological validity and complements traditional self-report scales [27].

Taken together, the findings underscore that success in chess extends beyond technical mastery and strategic knowledge. Psychological resources, particularly emotional intelligence and mental toughness, play a vital role in sustaining performance during prolonged cognitive challenges. The interplay of these traits suggests that mental preparation and emotional regulation are core components of excellence in cognitive sports such as chess.

Limitations and Future Directions

This study has several limitations that should be considered when interpreting the findings. The sample was limited to national-level chess players from the North-Eastern region of India, which may restrict the generalizability of the results to other cultural or competitive contexts. The cross-sectional design also prevents causal inferences regarding the relationship between emotional intelligence and mental toughness.

Future research should employ longitudinal designs to track the development of these psychological attributes across different stages of athletic experience. Experimental or intervention-based studies could further clarify whether targeted psychological training enhances emotional and cognitive resilience. Incorporating physiological and observational measures, such as heart rate variability, cortisol levels, or eye tracking during gameplay, would provide more comprehensive insight into stress responses and emotion–cognition interaction in competitive settings.

Expanding research to include players of different competitive levels and cultural backgrounds could deepen understanding of psychological variability in chess and other cognitively demanding sports.

Conclusions

This study highlights the significance of psychological factors such as emotional intelligence and mental toughness in chess performance. These attributes jointly contribute to emotional regulation, resilience, and cognitive stability under competitive pressure. The findings emphasize the value of integrating psychological preparation into chess training programs, with a focus on emotional control and stress management. Strengthening these mental components may enhance players' ability to sustain performance in cognitively demanding environments and support long-term psychological development in sport.

In the broader framework of physical culture and rehabilitation, the development of emotional intelligence and mental toughness may serve not only competitive performance but also psychological balance, self-regulation, and overall well-being. These findings suggest that cognitive sports like chess can be effectively integrated into recreational and educational programs that aim to enhance mental resilience and adaptive capacity.

Highlight

This study offers a psychological characterization of national-level chess players from the North-Eastern region of India, focusing on emotional intelligence (EI) and mental toughness (MT) across gender and age groups. It represents one of the first systematic investigations into cognitive sport performance within this underrepresented population. The results showed that female players demonstrated higher EI, while age was associated with increased MT, suggesting that experience enhances psychological resilience. A moderate positive correlation between EI and MT indicates their complementary roles in sustaining cognitive performance under competitive pressure. The use of validated assessment tools and appropriate statistical analyses supports the reliability of the findings. These outcomes underscore the importance of integrating structured psychological preparation into chess training, highlighting the growing relevance of emotional and mental skills in cognitive sports.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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