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Developing Middle School Students' Interest in Physical Education: A Pedagogical Model and Experimental Results

Fostering sustained interest in physical education among middle school students is regarded as an important factor in improving the effectiveness of school physical education within the framework of the updated educational content in the Republic of Kazakhstan. At the same time, declining student motivation highlights the need for pedagogical approaches that can enhance students' engagement in the educational process. The purpose of this study was to develop and experimentally evaluate a pedagogical model aimed at fostering middle school students' interest in physical education. The study was conducted at Kanysh Satpayev Gymnasium in Karaganda, Kazakhstan, and involved students from Grades 6B and 6G. The research methods included a review of the scientific literature, a questionnaire survey, pedagogical observation, physical fitness testing, a pedagogical experiment, and statistical analysis. The proposed pedagogical model was based on the integrated use of game-based, interactive, and digital educational technologies designed to enhance students' cognitive engagement and personal interest in physical education. The experimental results demonstrated a positive change in students' level of interest in physical education: the proportion of students with a high level of interest increased from 22.39% to 44.48%, whereas the proportion of students with a low level of interest decreased from 27.22% to 15.16%. In addition, improvements in the physical fitness of students in the experimental group were observed. The findings provide evidence supporting the effectiveness of the proposed pedagogical model and suggest its potential applicability to the organization of physical education in general secondary schools in the Republic of Kazakhstan.

Keywords: physical education, school physical education, middle school students, interest in physical education, pedagogical model, learning motivation, pedagogical experiment, physical fitness, digital educational technologies.

Introduction

In the context of the ongoing development of the secondary education system in the Republic of Kazakhstan, particular emphasis is placed on improving the quality of physical education, creating conditions that foster students' sustained motivation to engage in physical activity, and implementing contemporary pedagogical approaches. These priorities are reflected in the Instructional and Methodological Letter of the Altynsarin National Academy of Education, On the Peculiarities of the Educational Process in General Secondary Schools of the Republic of Kazakhstan in the 2025-2026 Academic Year, which highlights the importance of enhancing the quality of physical education lessons, applying modern teaching approaches, and fostering a sustainable commitment to a healthy lifestyle among schoolchildren [1].

According to the Model Curriculum for the Subject Physical Education for Grades 5–9 of Basic Secondary Education, one of the expected learning outcomes is the development of students' sustained motivation to participate in physical education, increased engagement in physical activity, and the development of physical fitness [2].

Over the past decade, the role of physical education in general secondary schools has expanded considerably. Alongside the development of motor abilities and physical fitness, school physical education is increasingly expected to contribute to students' health literacy, social development, emotional well-being, and the formation of lifelong habits of physical activity. These expectations have become particularly relevant in the context of declining daily physical activity among adolescents, the growing influence of digital technologies on leisure behavior, and increasing concerns about sedentary lifestyles. Under such conditions, the effectiveness of physical education depends not only on curriculum content but also on students' willingness to participate actively in the learning process [3].

For this reason, researchers have paid increasing attention to students' interest in physical education as one of the key determinants of successful learning. Regular attendance alone does not guarantee meaningful engagement in classroom activities. School practice demonstrates that many students formally participate in physical education lessons while remaining passive during learning tasks and showing little motivation to continue physical activity outside school. Such attitudes gradually reduce participation in organized exercise and weaken the educational value of physical education. Consequently, sustaining students' interest has become an important objective of contemporary physical education research [4].

Current theoretical approaches also reflect a shift in understanding the nature of interest itself [5]. Earlier psychological theories often described interest as a relatively stable personal characteristic. More recent studies, however, emphasize its dynamic character, arguing that interest develops through continuous interaction between the learner and the educational environment. From this perspective, students' attitudes toward physical education are shaped not only by individual characteristics but also by lesson organization, teacher–student interaction, learning experiences, and the overall educational climate. This understanding places greater responsibility on teachers to create learning environments capable of maintaining students' engagement over time.

These developments have stimulated extensive research into pedagogical approaches designed to strengthen students' motivation and participation in physical education. Recent studies have examined the educational potential of game-based learning, gamification, cooperative learning, digital educational technologies, and individualized instruction. Although these approaches differ in methodology, many authors arrive at a similar conclusion: improvements in students' motivation depend less on the isolated use of innovative teaching techniques than on the way these techniques are integrated into everyday classroom practice. In other words, the educational value of individual methods is largely determined by the coherence of the instructional process rather than by the methods themselves [6].

Despite substantial progress in this area, an important limitation remains. Much of the existing literature evaluates the effectiveness of individual teaching strategies, whereas considerably less attention has been devoted to comprehensive pedagogical models that combine several educational approaches within a single instructional framework. This distinction is particularly important because physical education lessons rarely rely on only one instructional strategy. Instead, teachers simultaneously employ different forms of interaction, digital resources, game activities, feedback techniques, and motivational tools. Understanding how these elements function together may provide a more realistic explanation of students' engagement than studying each approach separately [7].

An additional challenge concerns the transferability of educational findings across different national contexts. The effectiveness of pedagogical innovations depends on curriculum requirements, school organization, teacher preparation, and the broader educational environment. For Kazakhstan, these issues have become especially relevant following the implementation of the updated secondary education curriculum, which emphasizes functional literacy, student autonomy, initiative, and learner-centered instruction. Although national researchers have examined various aspects of physical education methodology, relatively few studies have investigated integrated pedagogical models specifically aimed at developing sustained interest in physical education among middle school students.

Against this background, the present study was designed to examine whether a pedagogical model integrating game-based, interactive, and digital educational technologies could improve middle school students' interest in physical education under the conditions of the updated school curriculum in the Republic of Kazakhstan. Unlike many previous studies that focused on the effectiveness of individual instructional tech-

niques, the present research evaluated the educational potential of a comprehensive pedagogical model implemented during regular physical education lessons [8].

The aim of the study was to develop and experimentally evaluate a pedagogical model for fostering middle school students' interest in physical education within the framework of the updated educational content implemented in the Republic of Kazakhstan.

Materials and Methods

Study Design

The research was carried out as a quasi-experimental study involving pre-test and post-test assessments of both a control and an experimental group. Such a design made it possible to evaluate changes in students' interest in physical education together with the dynamics of their physical fitness during one academic year.

The study was conducted at Kanysh Satpayev Gymnasium in Karaganda (Republic of Kazakhstan). The pedagogical intervention covered the entire school year and included three consecutive stages. During the initial stage, baseline data describing students' interest in physical education and their level of physical fitness were collected. The second stage focused on implementing the proposed pedagogical model during regular physical education lessons in the experimental group. At the end of the academic year, both groups completed the same assessment procedures, allowing the effectiveness of the intervention to be evaluated through comparative analysis.

Participants

Fifty-eight sixth-grade students aged 11-12 years participated in the study. Twenty-nine students from Grade 6B formed the control group, whereas twenty-nine students from Grade 6G comprised the experimental group.

Because the research was conducted under ordinary school conditions, students were not randomly assigned to groups. Existing school classes participated in the experiment without changes to their composition. Both groups followed the same curriculum and attended three physical education lessons per week. Before the intervention began, all participants completed identical baseline assessments to ensure comparability of the initial characteristics under investigation.

Research Methods

Several complementary research methods were employed.

A review of scientific and methodological literature was undertaken to identify current approaches to developing students' interest in physical education and to provide the theoretical basis for the proposed pedagogical model.

Pedagogical observation was used throughout the study to record students' participation during lessons, their interaction with teachers and classmates, and the degree of engagement demonstrated while performing learning tasks.

Students' interest in physical education was assessed using the diagnostic methodology developed by N.G. Luskanova [9].

Physical fitness was evaluated through a battery of standardized motor tests including a 30-m sprint, standing long jump, medicine ball throw, handgrip strength, pull-ups, a 3 × 10-m shuttle run, and the seated forward bend [10].

Pedagogical Intervention

Only the experimental group participated in the pedagogical intervention. Physical education lessons were organized according to the developed pedagogical model integrating game-based learning, interactive teaching methods, and digital educational technologies into regular classroom practice.

The control group continued studying according to the standard physical education curriculum without modifications to lesson organization or instructional content.

The effectiveness of the proposed model was determined by comparing pre-test and post-test indicators of students' interest in physical education together with changes in physical fitness observed in both groups.

Statistical Analysis

The collected data were processed using Microsoft Excel.

Descriptive statistical analysis included calculation of the arithmetic mean (M), standard deviation (SD), standard error of the mean (SEM), and coefficient of variation (CV). These indicators were used to summarize the experimental data and to compare the results obtained before and after the pedagogical intervention [11].

Ethical Considerations

The study complied with generally accepted ethical principles governing pedagogical research involving schoolchildren.

Participation in the study was voluntary. Before the beginning of the experiment, students and their parents received information about the objectives and procedures of the research. Oral informed consent for children's participation was obtained from parents prior to data collection.

Results and Discussion

The baseline assessment showed that, prior to the pedagogical intervention, students with a moderate level of interest in physical education predominated in both groups (Table 1). Their proportion accounted for 47.25 % in the control group and 50.35 % in the experimental group. A high level of interest was identified in 31.02 % of students in the control group and 22.39 % of those in the experimental group, whereas a low level of interest was observed in 21.72 % and 27.22 %, respectively.

The initial distribution indicates that the two groups were generally comparable at baseline. However, the experimental group demonstrated a less favorable distribution of interest levels, with a lower proportion of students exhibiting a high level of interest and a higher proportion demonstrating a low level of interest compared with the control group. This baseline difference provided an appropriate basis for evaluating the effectiveness of the proposed pedagogical model.

Table 1

Baseline Levels of Students' Interest in Physical Education Prior to the Pedagogical Experiment

Group	High level, %	Moderate level, %	Low level, %
Control group (n = 29)	31.02	47.25	21.72
Experimental group (n = 29)	22.39	50.35	27.22

The baseline questionnaire survey identified the main factors influencing students' attitudes toward physical education classes [12]. The findings showed that students expressed the greatest interest in game-based and competitive activities, team tasks, and exercises involving active interaction with their peers. Participants also emphasized the value of incorporating music and digital educational resources, which contributed to greater engagement and a more positive emotional atmosphere during lessons.

Conversely, the most frequently reported factors reducing students' interest included repetitive lesson content, limited variety of exercises, restricted opportunities to choose physical activities, and insufficient use of game-based teaching methods. These findings were taken into account when developing the proposed pedagogical model, which integrated game-based, interactive, and digital learning technologies into a unified instructional framework [13].

The post-intervention assessment demonstrated positive changes in both groups; however, the magnitude of improvement differed considerably (Table 2). In the experimental group, the proportion of students with a high level of interest increased by 22.09 percentage points, while the proportion of those with a low level of interest decreased by 12.06 percentage points. In the control group, the corresponding changes were +6.90 and -3.80 percentage points, respectively.

Overall, the results indicate that the educational intervention produced a substantially greater effect in the experimental group, where the increase in the proportion of students with a high level of interest was more than three times greater than that observed in the control group.

Table 2

Changes in Students' Interest Levels Following the Educational Intervention

Group	Change in high level (percentage points)	Change in moderate level (percentage points)	Change in low level (percentage points)
Control group	+6.90	-3.11	-3.80
Experimental group	+22.09	-10.01	-12.06

The observed changes in students' motivational profiles were accompanied by improvements in the physical fitness of the experimental group, suggesting a possible association between increased interest in physical education and more effective achievement of the intended learning outcomes (Table 3).

Table 3

Changes in the Physical Fitness Indicators of Students in the Experimental Group Before and After the Educational Intervention

Physical fitness test	Boys Before (M ± m)	Boys After (M ± m)	Improvement, %	Girls Before (M ± m)	Girls After (M ± m)	Improvement, %
30-m sprint, s	5.90±0.11	5.20±0.06	11.86	6.20±0.09	5.44±0.13	12.26
Handgrip strength (left), kg	9.68±0.14	27.93±1.07	188.53	6.00±0.19	21.18±0.80	253.00
Handgrip strength (right), kg	10.43±0.29	28.43±0.98	172.58	9.27±0.29	21.09±0.70	127.51
Standing long jump, cm	160.19±4.46	176.93±3.50	10.45	147.90±3.69	168.00±2.00	13.59
Medicine ball throw, cm	349.09±10.48	471.56±18.28	35.08	373.12±13.17	501.91±20.95	34.52
Pull-ups, repetitions	5.50±0.95	9.10±1.02	65.45	10.81±0.49	17.09±1.10	58.09
Shuttle run (3 × 10 m), s	9.75±0.11	8.64±0.11	11.38	10.04±0.14	8.90±0.11	11.35
Sit-and-reach test, cm	3.25±0.21	5.68±0.43	74.77	8.90±0.69	15.45±1.00	73.60

The results of the post-intervention fitness assessment demonstrated positive changes across all measured physical fitness indicators in the experimental group following the implementation of the proposed pedagogical model (Table 3). The largest gains were observed in measures of muscular strength and flexibility. Among boys, the greatest percentage increases were recorded for handgrip strength (188.53 % and 172.58 %), pull-up performance (65.45 %), and flexibility (74.77 %). Similarly, among girls, the most pronounced improvements were found in handgrip strength (253.00 % and 127.51 %), the sit-and-reach test (73.60 %), and pull-up performance (58.09 %). More moderate, yet consistent, improvements were observed in tests assessing speed, coordination, and speed–strength abilities.

Overall, improvements were observed across all measured physical fitness indicators in the experimental group. The greatest gains were recorded in strength- and flexibility-related tests, whereas more moderate changes were found in measures of speed and coordination.

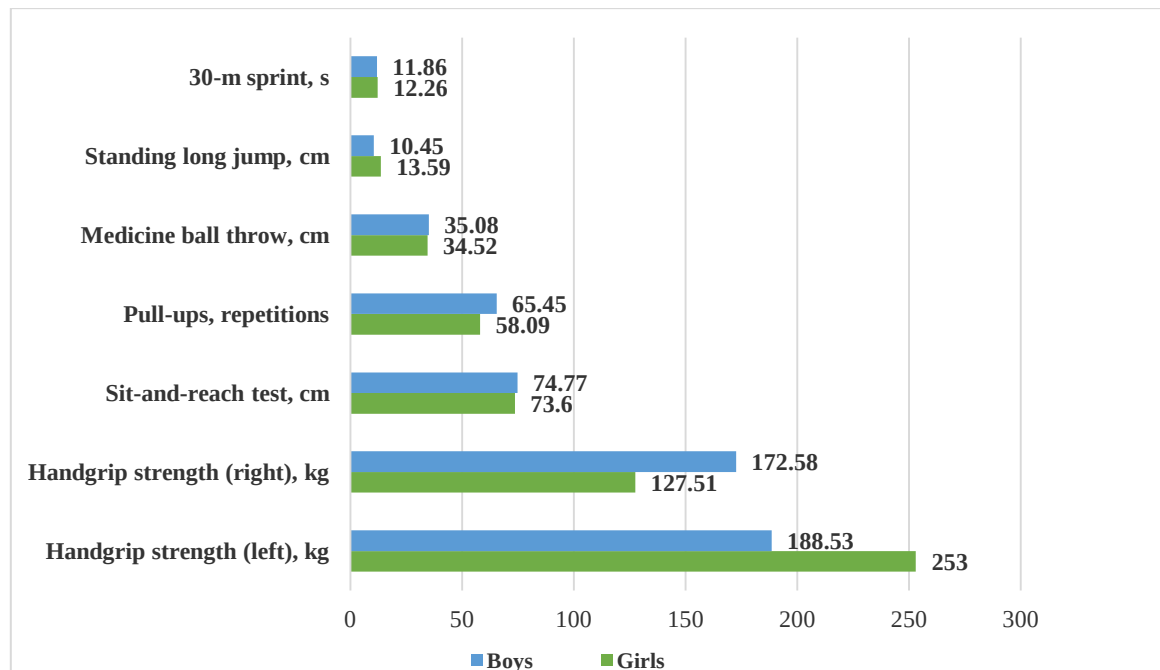


Figure 1. Percentage Changes in Physical Fitness Indicators of Boys and Girls in the Experimental Group After the Educational Intervention

The findings of the present study indicate that the proposed pedagogical model contributed to improvements not only in students' interest in physical education but also in their physical fitness. The most pronounced changes were observed in the experimental group, where an increase in the proportion of students with a high level of interest was accompanied by better performance across most physical fitness tests. These findings suggest that greater engagement in learning activities may create more favorable conditions for active participation in physical education and more effective acquisition of movement skills.

The results support the view that students' interest in physical education represents an important pedagogical resource capable of influencing learning outcomes [14]. Rather than being attributable to the use of isolated instructional techniques, the observed improvements appear to be associated with the integrated organization of the lesson. In the proposed model, game-based activities, interactive learning strategies, and digital educational tools were combined within a unified instructional framework, allowing each component to reinforce the others in achieving common educational objectives.

These findings are consistent with previous research addressing student motivation in physical education [15]. Systematic reviews have shown that game-based learning, digital educational resources, and gamification can increase students' motivation and engagement in physical education. However, considerably less attention has been paid to their influence on physical fitness and the long-term sustainability of motivational changes. Unlike most previous studies, which evaluated individual instructional approaches, the present study examined the effectiveness of integrating several complementary pedagogical strategies within a single educational model.

The findings are also consistent with the four-phase model of interest development proposed by Renninger and Hidi, according to which sustained interest develops progressively through interaction between learners and their educational environment [16]. From this perspective, game-based, interactive, and digital learning approaches should not be viewed as independent motivational tools but rather as complementary elements of an educational environment that supports students' active participation in learning.

Similar conclusions have been reported by Jastrow et al., who demonstrated that the effectiveness of digital educational technologies depends largely on the quality of their pedagogical integration into physical education lessons [17]. Likewise, Fernández-Espínola, Ferriz-Valero, Quintas, and their colleagues associated improvements in students' motivation with cooperative learning and gamification strategies [18, 19]. Nevertheless, most previous studies have focused on the effects of individual instructional approaches, whereas considerably less attention has been devoted to examining their combined implementation. The findings of the present study suggest that integrating several complementary pedagogical strategies may produce greater educational benefits than their isolated application.

Several limitations should be acknowledged. The study was conducted in a single general education school and involved only sixth-grade students. In addition, the intervention lasted for one academic year. Therefore, caution should be exercised when generalizing the findings to other age groups and educational settings. Future research should examine the effectiveness of the proposed pedagogical model in different school contexts and evaluate the long-term sustainability of the observed outcomes.

Conclusion

The findings of this study demonstrate that fostering students' sustained interest in physical education largely depends on the organization of the educational process. The implementation of the proposed pedagogical model was associated with an increase in the proportion of students demonstrating a high level of interest in physical education, accompanied by improvements in physical fitness indicators. The results suggest that integrating game-based, interactive, and digital learning approaches within a unified instructional framework provides favorable conditions for enhancing students' interest in physical education while supporting improvements in physical fitness.

The proposed pedagogical model has practical value for general secondary schools, as it can be implemented within the existing physical education curriculum without requiring substantial modifications to its content. The model may also serve as a methodological framework for planning physical education lessons and organizing extracurricular physical activity programs.

Several limitations should be acknowledged. The study was conducted in a single general education school and included only sixth-grade students. Consequently, further research is needed to examine the effectiveness of the proposed model across different age groups and educational settings. Future studies should also investigate the long-term impact of the intervention and evaluate its effectiveness under diverse organizational and pedagogical conditions.

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Dynamics of the Competitiveness of Russian Male and Female Pole Vaulters During the 2020–2024 Olympic Cycle

The level of competitiveness in pole vaulting reflects not only athletic performance but also the effectiveness of athlete development within the discipline. This study examines changes in the competitive dynamics of Russian male and female pole vaulters during the 2020–2024 Olympic cycle and identifies factors associated with these changes. The analysis was based on official results from the Russian Indoor and Outdoor Athletics Championships. Competitive dynamics were assessed using a combination of literature review, comparative analysis of competition results, calculation of competitiveness coefficients, statistical analysis, and expert consultations with experienced pole vault specialists. The results indicate a gradual decline in competitiveness in the women's event, accompanied by lower performance density and a widening gap between leading athletes and the remainder of the field. In contrast, the men's event demonstrated relatively stable competitive characteristics throughout the study period. These findings provide an empirical assessment of the current state of the discipline and may contribute to improving long-term athlete development, optimizing competition planning, and monitoring the effectiveness of pole vault development programmes.

Keywords: pole vault, athletics, competitiveness, competitive performance, competitiveness coefficient, athletic reserve, Olympic cycle, competition results.

Introduction

Pole vault is one of the most technically demanding disciplines in athletics [1]. High athletic performance in this event depends not only on athletes' physical fitness but also on technical proficiency, psychological resilience, the quality of training facilities and equipment, and the effective organization of the training process [2, 3, 4]. The high level of competition at major championships places increasing demands on athlete preparation systems and necessitates continuous analysis of the factors determining successful competitive performance [5].

For many years, the Russian pole vault school has maintained a leading position in international athletics. Russian athletes have repeatedly won medals at the Olympic Games, World Championships, and European Championships, setting world records and contributing substantially to the development of the discipline. These achievements demonstrate the effectiveness of the national athlete development system and its significant contribution to the advancement of pole vaulting.

In recent years, however, Russian athletics has undergone substantial changes in its competitive environment. Limited participation of Russian athletes in international competitions, modifications to the national competition calendar, and generational changes among elite athletes have affected the intensity of domestic competition [6]. Under these circumstances, an objective assessment of the competitiveness of the discipline has become increasingly important for identifying development trends and evaluating the depth of the national talent pool.

Recent studies have primarily focused on improving pole vault technique, optimizing training methodologies, and analyzing competitive performance [2]. However, changes in the competitiveness of Russian pole vaulters throughout the 2020–2024 Olympic cycle have received relatively little attention. Most published studies have been limited to analyses of individual competition results or the performances of elite athletes, whereas comprehensive evaluations of changes in the competitive environment remain scarce [7].

The competitiveness of a sports discipline can be regarded as an integrated indicator reflecting its level of development, the depth of the athletic reserve, and the intensity of competitive rivalry. Analysis of its dynamics provides not only an assessment of elite athletic performance but also an understanding of broader developmental trends and changes occurring within the athlete preparation system.

Therefore, a comprehensive investigation of the competitiveness of Russian male and female pole vaulters based on the results of the major national competitions held during the 2020–2024 Olympic cycle is warranted.

The aim of the study was to examine the dynamics of the competitiveness of Russian male and female pole vaulters during the 2020–2024 Olympic cycle and to identify the factors influencing its changes.

Materials and Methods

The aim of this study was to examine the dynamics of the competitiveness of Russian male and female pole vaulters during the 2020–2024 Olympic cycle and to identify the factors influencing its development [8, 9].

The empirical basis of the study consisted of the official results of the Russian National Indoor and Outdoor Athletics Championships held between 2020 and 2024. The analysis included performances of athletes specializing in pole vault who held sports qualifications ranging from Candidate for Master of Sport (CMS) to Master of Sport of International Class (MSIC). The study covered ten national championships (five indoor and five outdoor competitions) conducted during the 2020–2024 Olympic cycle. The final dataset comprised 4,560 individual performances.

To achieve the study objective, a combination of complementary research methods was employed. A review and synthesis of the scientific literature were conducted to establish the current state of knowledge and identify existing approaches to evaluating competitive performance in athletics. Official competition results were analyzed to compile a database of athletes' performances and to conduct comparative analyses [10]. Comparisons of competition results across different years enabled the identification of changes in competitiveness throughout the Olympic cycle.

When interpreting the findings, consideration was given to the structure of the national competition calendar, changes in participant composition, and external factors that could influence the competitive environment.

Competitiveness was quantitatively assessed using a Competitiveness Coefficient (CompC), which reflects the density of athletes' performances within a competition [11, 12]. The coefficient was calculated separately for each championship, enabling year-to-year comparisons of competitiveness throughout the Olympic cycle. CompC was determined as the ratio between the cumulative performances of athletes ranked in the upper half and those ranked in the lower half of the final competition standings [13].

An increase in CompC indicated greater performance density and a higher level of competitive rivalry, whereas a decrease reflected reduced competitiveness of the discipline and a widening performance gap between the leading athletes and the remaining competitors.

The use of CompC made it possible to evaluate not only the performance level of elite athletes but also the depth of the national talent pool and the developmental trends of the discipline throughout the study period.

Statistical analyses were performed using Microsoft Excel and Statistica software. Mean values, absolute changes, and CompC values were calculated. The results are presented in tables and figures to illustrate changes in competitiveness in both men's and women's pole vault events.

To support the qualitative interpretation of the findings, consultations were conducted with experienced pole vault coaches and specialists involved in the preparation of high-performance athletes. Their expert opinions were used exclusively to assist in interpreting the results and were not included as an independent source of statistical evidence.

Only the official results of the Russian National Championships published by the Russian Athletics Federation were included in the analysis. Athletes who recorded No Valid Result (NVR) and performances subsequently invalidated by official decisions of the judging panel were excluded from the dataset. These selection criteria ensured data comparability and enhanced the reliability of the findings [14].

Results and Discussion

The dynamics of athletic performance in men's and women's pole vault were analyzed using the official results of the Russian National Athletics Championships held during the 2020–2024 Olympic cycle. The best performances achieved during this period are presented in Tables 1 and 2.

Table 1

**Top 12 performances in the women's pole vault at
the Russian National Championships during the 2020–2024 Olympic cycle**

Place	2020i	2021i	2022i	2022	2023	2023i	2024	2024i
1	4.92	4.75	4.65	4.91	4.70	4.62	4.73	4.73
2	4.65	4.65	4.55	4.65	4.55	4.55	4.45	4.63
3	4.60	4.55	4.45	4.45	4.50	4.55	4.45	4.63
4	4.55	4.55	4.45	4.35	4.40	4.45	4.45	4.35
5	4.45	4.45	4.45	4.25	4.30	4.45	4.35	4.35
6	4.45	4.35	4.35	4.25	4.30	4.35	4.35	4.20
7	4.35	4.35	4.25	4.10	4.30	4.20	4.35	4.20
8	4.25	4.25	4.25	4.10	4.20	4.05	4.20	4.20
9	4.10	4.10	4.10	4.10	4.20	4.05	3.70	3.90
10	4.10	4.10	4.10	4.10	4.10	3.90	3.70	-
11	3.95	3.95	4.10	3.90	4.10	-	-	-
12	3.90	3.95	3.95	3.65	4.10	-	-	-

Table 2

**Top 12 performances in the men's pole vault at the Russian National Championships
during the 2020–2024 Olympic cycle**

Place	2020i	2021	2021i	2022	2022i	2023	2023i	2024	2024i
1	5.65	5.80	5.55	5.70	5.75	5.87	5.65	5.72	5.82
2	5.55	5.55	5.55	5.65	5.55	5.82	5.65	5.72	5.77
3	5.55	5.55	5.45	5.60	5.45	5.77	5.45	5.60	5.66
4	5.55	5.45	5.45	5.40	5.30	5.50	5.45	5.50	5.53
5	5.45	5.45	5.45	5.40	5.30	5.40	5.30	5.30	5.53
6	5.45	5.45	5.30	5.40	5.30	5.30	5.30	5.30	5.45
7	5.30	5.35	5.30	5.30	5.15	5.30	5.30	5.30	5.45
8	5.30	5.35	5.15	5.30	5.15	5.30	5.30	5.30	5.45
9	5.30	5.15	5.15	5.30	5.15	5.15	5.30	5.30	5.30
10	5.30	5.15	5.15	5.15	5.15	5.15	5.30	5.15	5.30
11	5.30	5.15	5.15	5.15	5.15	-	5.15	4.60	5.15
12	5.00	5.00	5.15	5.15	5.15	-	5.00	4.60	5.00

The results demonstrate that the highest performances remained consistently high in both the men's and women's events throughout the study period. However, the distribution of performances within each group revealed notable differences in competitive density. In the women's event, while the leading athletes continued to achieve elite-level results, performances among lower-ranked competitors showed greater variability, indicating a gradual decline in the overall competitiveness of the discipline. In contrast, men's pole vault demonstrated a more homogeneous distribution of results, reflecting a relatively stable competitive environment.

To quantify changes in competitiveness, the Competitiveness Coefficient (CompC) was calculated separately for men's and women's competitions (Tables 3 and 4). This indicator reflects the density of

athletes' performances within each championship and enables comparisons across different years of the Olympic cycle.

Table 3

**Competitiveness Coefficient (CompC) for Women's Pole Vault
at the Russian National Championships (2020–2024)**

2020i	2021i	2022i	2022i	2022	2023	2023i	2024	2024i
0.89	0.90	0.92	0.92	0.89	0.93	0.60	0.59	0.44

Table 4

**Competitiveness Coefficient (CompC) for Men's Pole Vault
at the Russian National Championships (2020–2024)**

2020i	2021	2021i	2022	2022i	2023	2023i	2024	2024i
0.94	0.93	0.94	0.94	0.94	0.62	0.95	0.91	0.93

In the women's event, CompC remained relatively high between 2020 and 2022, ranging from 0.89 to 0.93. A marked decline was observed from 2023 onwards, with the coefficient decreasing to 0.60 at the 2023 Indoor Championships, 0.59 at the 2024 Outdoor Championships, and 0.44 at the 2024 Indoor Championships. These findings indicate a substantial reduction in performance density and an increasing performance gap between the leading athletes and the remaining competitors [15].

A different pattern was observed in the men's event. With the exception of one isolated decrease during the 2023 Outdoor Championships (CompC = 0.62), competitiveness remained consistently high throughout the Olympic cycle, with coefficient values generally ranging between 0.91 and 0.95. These results suggest that men's pole vault maintained a stable competitive structure and a sufficient depth of high-level athletes.

Figures 1 and 2 illustrate the temporal changes in CompC for women's and men's competitions, respectively. The graphical analysis confirms the contrasting trends observed in the coefficient analysis. Women's pole vault demonstrated a progressive decline in competitiveness, whereas the men's event maintained a relatively stable level of competitive density throughout the study period.

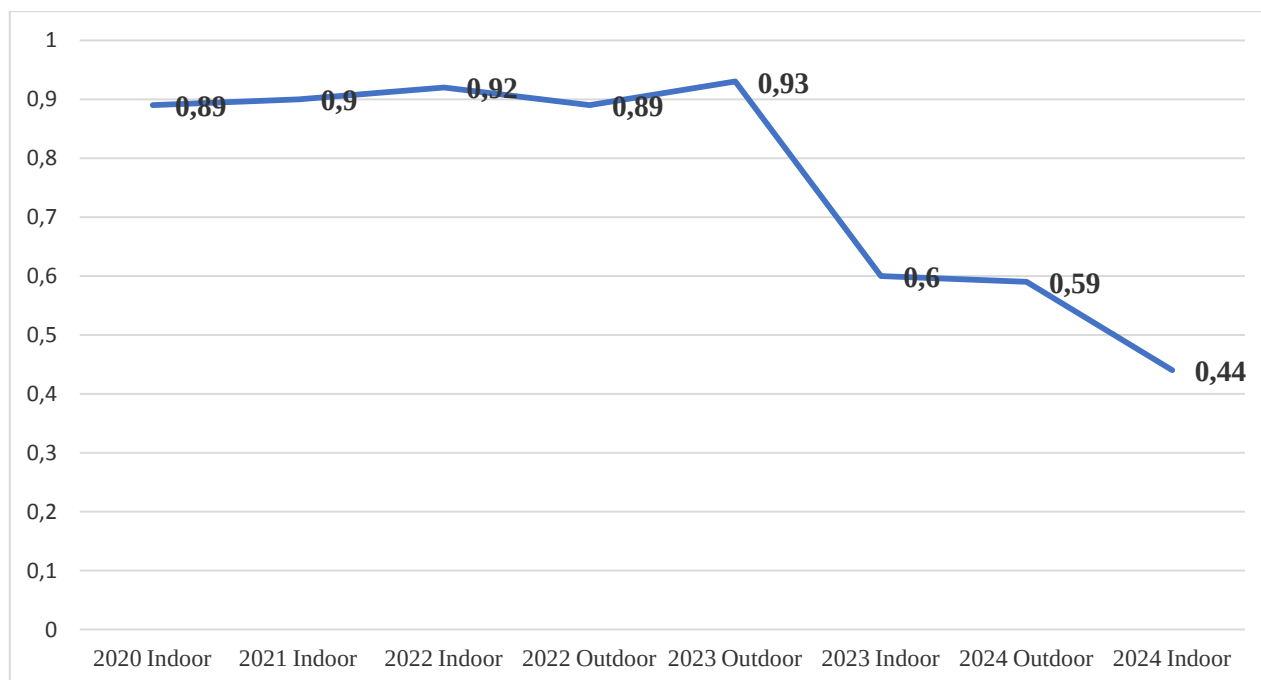


Figure 1. Dynamics of the Competitiveness Coefficient (CompC) in Women's Pole Vault at the Russian National Championships during the 2020–2024 Olympic Cycle

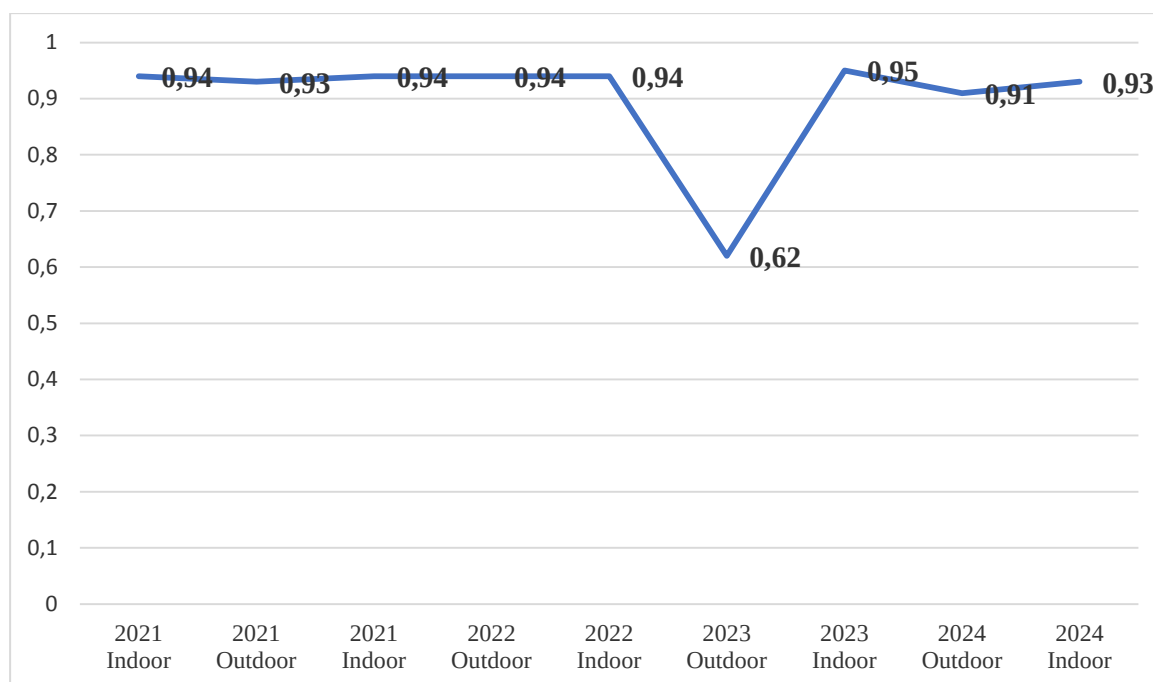


Figure 2. Dynamics of the Competitiveness Coefficient (CompC) in Men's Pole Vault at the Russian National Championships during the 2020–2024 Olympic Cycle

The present findings indicate divergent developmental trends in Russian pole vault during the 2020–2024 Olympic cycle. Although the performance level of the leading female athletes remained consistently high, the decreasing competitiveness coefficient suggests a reduction in the overall depth of the discipline. One possible explanation is the decline in the number of athletes participating in national championships. The expert consultations suggested that financial limitations faced by regional sports organizations could have influenced athlete participation in national competitions [16]. Several coaches noted that travelling to championships held in distant regions had become more difficult because of restricted funding. This explanation is consistent with the competition data. Championships conducted in Moscow and Chelyabinsk, where long-established pole vault training centres are located, attracted considerably more competitors than those held in Yekaterinburg. These differences in participation indicate that the geographical location of competitions, together with available financial support, may influence the competitive field [17].

The situation in the men's event differed from that observed in the women's competition. Throughout the 2020–2024 Olympic cycle, the level of competitiveness remained relatively stable. Leading athletes consistently achieved high performances, while new competitors regularly entered the national rankings. Taken together, these observations suggest that the current athlete development system continues to provide a sufficient reserve of talented male pole vaulters [5].

During the consultations, experts also discussed several issues that may become increasingly important in the coming years. Although regional training centres continue to produce successful athletes, specialists expressed concern about the gradual retirement of experienced coaches and the declining number of qualified coaching personnel. If this tendency continues, it may affect the continuity of athlete preparation and reduce the effectiveness of long-term training programmes. Similar concerns have been described in studies devoted to other sports, where the preservation of coaching expertise is regarded as an essential factor for maintaining competitive performance [18].

The changes observed in the women's event appear to be associated with several additional factors. One of them is the retirement of athletes who had represented Russia successfully at the international level for many years. Their departure reduced the number of competitors capable of achieving performances comparable with international standards, contributing to a wider gap between the leading athletes and the rest of the field. Experts also reported that fewer young women have recently chosen to specialize in pole vault. In their opinion, the limited opportunity to compete at major international events may have weakened motivation among young athletes and made the discipline less attractive as a long-term sporting career [7].

Conclusion

Analysis of the Russian National Athletics Championships over the 2020–2024 Olympic cycle showed that the men's and women's pole vault events followed different patterns of development. These differences were reflected in both the Competitiveness Coefficient (CompC) and the distribution of athletes' performances, indicating changes in the overall structure of national competition.

In the women's event, the leading athletes maintained consistently high performance levels throughout the Olympic cycle, whereas the gap between the leaders and the remaining competitors gradually widened. Together with the decline in the CompC, this suggests a gradual reduction in competitive depth. As fewer athletes approached the performance level of the leaders, opportunities for further progress through internal competition became more limited.

A different picture emerged in the men's event. Although the CompC varied slightly between individual championships, these fluctuations were not accompanied by meaningful changes in the overall distribution of performances. Across the Olympic cycle, a relatively broad group of athletes continued to compete at a consistently high level, indicating that the men's discipline retained both competitive stability and sufficient performance depth.

Overall, the analysis indicates that the two events followed different developmental paths during the Olympic cycle.

The present findings do not allow causal conclusions. Nevertheless, the observed trends may be associated with broader organizational and structural characteristics of the national athlete development system.

The methodological approach presented in this study may be used to monitor changes in competitiveness and to assist in evaluating athlete development programmes and national competition systems. Future studies should include longer observation periods, comparisons with international competitions, and further refinement of competitiveness indicators for technically demanding athletics events.

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Pedagogical Conditions for Improving Technical and Tactical Training of Young Football Players Through Game-Based Exercises

Improving the technical and tactical training of young football players requires the development of pedagogical approaches that ensure the integration of technical and tactical training within a unified training process. The aim of the study was to theoretically substantiate, develop, and experimentally test a pedagogical model for improving the technical and tactical training of young football players aged 8–10 years, based on the implementation of a set of pedagogical conditions through the systematic use of game-based exercises. The study involved 24 young football players who were divided into control and experimental groups. The research methods included analysis of scientific and methodological literature, pedagogical observation, a pedagogical experiment, pedagogical testing, and mathematical statistical methods. Following the completion of the pedagogical experiment, the experimental group demonstrated more pronounced positive dynamics across all studied indicators compared with the control group. The most substantial changes were observed in the accuracy of shots and tactical preparedness. The results indicate more pronounced positive dynamics in technical and tactical preparedness under the comprehensive implementation of the pedagogical conditions compared with the traditional organization of the training process. The developed pedagogical model may be recommended for use at the initial stage of football training, taking into account the observed positive dynamics of the indicators associated with the integration of technical and tactical training through game-based activities.

Keywords: young football players; technical and tactical training; pedagogical conditions; pedagogical model; game-based exercises; decision-making; training process; youth football.

Introduction

The modern system of training young football players places increasingly high demands on their level of technical and tactical preparedness. Already at the initial stage of sports development, the effectiveness of game actions is determined not only by the quality of technical skill execution but also by the ability to perceive the game situation in a timely manner, make an optimal decision, and implement it effectively under opposition from an opponent. Therefore, technical and tactical training is considered a unified pedagogical process in which the improvement of technical skills is inextricably linked to the development of tactical thinking [1-2].

Despite the widespread use of game-based exercises in youth football practice, their role within the structure of the training process remains ambiguous. In many cases, game-based exercises are used primarily as an auxiliary component of a training session, either concluding the main part of the session or serving to increase the participants' emotional engagement. At the same time, the teaching of technical skills is still predominantly based on repeated performance of motor elements under relatively stable conditions. Such an organization of training contributes to the acquisition of individual technical skills but is less effective in developing the ability to apply them in rapidly changing game situations [3].

This contradiction is particularly evident in the training of football players aged 8–10 years. It is during this age period that the foundations of ball-handling technique are established, initial concepts of interaction with teammates are formed, and the ability to orient themselves in game situations develops. At the same time, a high need for play remains a characteristic feature of children of this age. Therefore, the effectiveness of the training process largely depends on the extent to which the content of training sessions corresponds to the age-specific characteristics of the participants while maintaining their natural cognitive and motor activity [4, 5].

In the studies reviewed, considerable attention is devoted to evaluating the effectiveness of individual game-based exercises, small-sided games, or improving specific technical components of young football players' training. Considerably less attention is paid to the pedagogical conditions that ensure their systemat-

ic use within the structure of the training process. Meanwhile, the findings of recent systematic reviews indicate that the effectiveness of game-based exercises depends not only on their content but also on the specific features of the pedagogical organization of training activities [1, 4–6].

In the present study, game-based exercises are considered not as an independent training tool but as the basis for developing a pedagogical model aimed at improving the technical and tactical training of young football players. Its effectiveness is based on a set of interrelated pedagogical conditions: gradual complication of game situations; integration of technical and tactical training within each training task; simulation of episodes of competitive activity; increasing each player's individual motor activity through the use of small-sided games; and systematic organization of game-based exercises throughout the training cycle. It is assumed that the comprehensive implementation of these pedagogical conditions creates a favorable educational environment for developing stable technical and tactical skills in young football players [7, 8].

Thus, the continuing contradiction between the need to prepare football players for effective actions in real game situations and the predominance of traditional teaching approaches determines the relevance of the present study.

Aim of the study — to theoretically substantiate, develop, and experimentally test a pedagogical model for improving the technical and tactical training of young football players aged 8–10 years, based on the implementation of a set of pedagogical conditions through the systematic use of game-based exercises.

Materials and Methods

The study was conducted at the Shakhtar Football Club Academy in Karaganda from September 2025 to April 2026. The pedagogical experiment involved 24 young male football players aged 8–10 years who were undergoing initial sports training. The study was conducted under natural training conditions, with the usual training schedule and duration of training sessions maintained. Prior to the study, verbal consent to the children's participation was obtained from their parents or legal guardians.

The methodological basis of the study was the concept of comprehensive development of technical and tactical preparedness, which assumes the interrelated development of technical skills and game-related thinking. In contrast to the traditional approach, which is primarily based on repeated performance of individual technical actions, the developed model provided for the systematic use of game-based exercises as the main means of organizing the training process.

The effectiveness of the proposed model was based on the implementation of the following pedagogical conditions: gradual complication of game situations as technical skills were acquired; integration of technical and tactical training into each training task; simulation of game episodes approximating competitive conditions; increasing the individual motor activity of each football player through the use of small-sided games; systematic use of game-based exercises at the initial stage of training.

The implementation of these pedagogical conditions was aimed not only at improving ball-handling skills but also at developing young football players' ability to make rational decisions in changing game situations, interact with teammates in a timely manner, and effectively apply the acquired technical skills under game opposition.

To achieve the aim of the study, a set of complementary research methods was used, including analysis of scientific and methodological literature, pedagogical observation, a pedagogical experiment, pedagogical testing, and methods of mathematical statistics.

The results of the developed pedagogical model were evaluated based on control tests characterizing the level of technical and tactical preparedness of the young football players. The testing program included exercises designed to assess the speed of motor actions with the ball, shooting accuracy, and the performance of game actions under conditions approximating those of competitive activity. The control tests were conducted before the beginning of the pedagogical experiment and after completion of the experimental program, allowing for a comparative analysis of the dynamics of the studied indicators.

Statistical processing of the experimental data was performed using methods of mathematical statistics. The results are presented as the arithmetic mean and the error of the arithmetic mean ($M \pm m$). Descriptive statistics were calculated for the analysis of the results, and the data were interpreted based on a comparison of the results of the control and experimental groups [9, 10].

Results and Discussion

Before the beginning of the pedagogical experiment, the technical and tactical preparedness of the young football players in the control and experimental groups was assessed. The assessment program includ-

ed control tests designed to evaluate the quality of basic technical actions, as well as the results of tactical testing. The data obtained were used for a comparative characterization of the study groups prior to the implementation of the developed pedagogical model.

Table 1

**Baseline indicators of the technical and tactical preparedness
of young football players before the pedagogical experiment ($M \pm m$)**

Control test	Control group (n = 12)	Experimental group (n = 12)
30-m ball dribbling, s	6.80 ± 0.17	6.87 ± 0.11
30-m shuttle run with the ball, s	8.25 ± 0.16	8.23 ± 0.17
Shooting accuracy, points	6.40 ± 0.45	6.16 ± 0.46
Tactical preparedness, points	42.83 ± 2.50	43.00 ± 2.87

As shown by the data presented in Table 1, before the beginning of the pedagogical experiment, the mean values of the studied indicators were similar in the control and experimental groups. The smallest differences were observed in the 30-m shuttle run with the ball (8.25 ± 0.16 and 8.23 ± 0.17 s) and in the assessment of tactical preparedness (42.83 ± 2.50 and 43.00 ± 2.87 points). Small differences were also observed in the indicators of ball dribbling and shooting accuracy, characterizing the baseline level of the studied indicators as similar in both groups.

Following the baseline testing, the pedagogical model aimed at improving the technical and tactical training of young football players through the systematic use of game-based exercises was implemented in the experimental group. In contrast to the traditional organization of the training process, game-based tasks were considered not as a separate element of the training session but as the main means of developing technical skills and tactical thinking.

The experimental program was developed based on the creation of pedagogical conditions facilitating the transfer of acquired motor skills to real game situations. Particular attention was paid to the relationship between technical and tactical training, the gradual complication of game tasks, and the organization of exercises that closely approximated competitive conditions.

The key pedagogical conditions underlying the implementation of the developed model are presented in Table 2.

Table 2

**Pedagogical Conditions for Improving the Technical and Tactical Training
of Young Football Players Through Game-Based Exercises**

Pedagogical condition	Implementation in the experimental program
Use of game-based exercises as the main means of instruction	Game-based tasks were systematically used throughout the pedagogical experiment
Gradual complication of exercise content	A gradual transition from simple game actions to exercises requiring game-related decision-making
Integration of technical and tactical training	Technical skills were developed in game situations requiring the selection of an effective course of action
Increasing motor activity	The organization of exercises ensured the continuous involvement of each football player in game actions
Approximating training tasks to competitive activity	Exercises were used to simulate typical game situations arising during a match

The pedagogical conditions presented in Table 2 were implemented not in isolation but within a unified system for organizing the training process. This approach made it possible to simultaneously improve the execution of game actions, develop decision-making skills, and enhance the ability to apply acquired technical skills under changing game conditions. It was assumed that the comprehensive implementation of the pedagogical conditions would result in greater gains in technical and tactical preparedness compared with the traditional organization of the training process.

Following the completion of the pedagogical experiment, the participants in the control and experimental groups underwent repeated testing using the same control tests as at the baseline stage of the study.

Comparison of the results before and after the implementation of the pedagogical model made it possible to assess changes in the technical and tactical preparedness of the young football players and to conduct a comparative analysis of the dynamics of the results in the control and experimental groups.

Table 3

Dynamics of Technical and Tactical Preparedness Indicators of Young Football Players Before and After the Pedagogical Experiment ($M \pm m$)

Control test	Control group — Before	Control group — After	Experimental group — Before	Experimental group — After
30-m ball dribbling, s	6.80 ± 0.17	6.50 ± 0.11	6.87 ± 0.11	6.45 ± 0.10
30-m shuttle run with the ball, s	8.25 ± 0.16	8.03 ± 0.15	8.23 ± 0.17	7.67 ± 0.12
Shooting accuracy, points	6.40 ± 0.45	7.25 ± 0.84	6.16 ± 0.46	8.30 ± 0.35
Tactical preparedness, points	42.83 ± 2.50	51.08 ± 3.05	43.00 ± 2.87	60.00 ± 2.22

The results of the repeated testing (Table 3) showed positive dynamics in the studied indicators in both groups, with more pronounced changes observed in the experimental group. The most substantial improvements were found in shooting accuracy and tactical preparedness. Improvements were also observed in the ball dribbling and shuttle run with the ball tests. Thus, based on the absolute values of the indicators, the experimental group demonstrated more pronounced positive dynamics compared with the control group.

However, a comparison of the absolute values does not fully reflect the differences in the performance of the approaches used. Therefore, the rates of increase for the studied indicators were calculated for each control test, allowing a comparative assessment of the results of the experimental pedagogical model (Table 4).

Table 4

Rates of Increase in Technical and Tactical Preparedness Indicators of Young Football Players After the Pedagogical Experiment

Control test	Control group, %	Experimental group, %
30-m ball dribbling	4.41	6.11
30-m shuttle run with the ball	2.67	6.80
Shooting accuracy	13.28	34.74
Tactical preparedness	19.26	39.53

The results of the implementation of the developed pedagogical model are more clearly reflected by the rates of increase in the studied characteristics (Table 4). The rate of increase was calculated as the ratio of the absolute increase in the indicator (AI) to its mean value at baseline (M_1), expressed as a percentage ($RI = AI \times 100 \% / M_1$). For time-based indicators, a reduction in completion time was considered a positive change. Analysis of the data obtained showed positive dynamics in both groups; however, the rate of increase was higher in the experimental group across all control tests.

The most pronounced differences were identified in the tests assessing the accuracy of technical actions and the level of tactical preparedness. Thus, the rate of increase in shooting accuracy in the experimental group was 34.74 %, whereas the corresponding value in the control group did not exceed 13.28 %. A similar pattern was observed in the assessment of tactical preparedness, where the increase in the experimental group reached 39.53 %, which was more than twice the corresponding value in the control group (19.26 %).

Less pronounced but consistent differences were also observed in the tests reflecting the players' technical preparedness. The rates of improvement in ball dribbling and the shuttle run with the ball were also higher in the experimental group than in the control group, indicating a positive effect of the pedagogical model on the quality of basic technical actions.

The results obtained suggest that the more pronounced dynamics observed in the experimental group were associated with the comprehensive organization of the training process, which included the systematic use of game-based exercises and interrelated pedagogical conditions. Technical skills were not acquired in isolation but under constantly changing game conditions requiring analysis of the game situation, selection of

the most appropriate course of action, and interaction with teammates. This approach was aimed at simultaneously improving the execution of game actions and developing elements of tactical thinking [11].

The findings generally agree with recent studies addressing game-based approaches to the training of young football players. In particular, studies have shown that training based on small-sided games and game-based tasks contributes to the development of decision-making skills, improvement of tactical behavior, and greater effectiveness of technical actions under conditions approximating competitive activity. At the same time, the authors emphasize that the magnitude of the positive effect depends not only on the content of the exercises but also on the principles underlying their pedagogical organization [12, 13, 14].

A similar trend can be observed in recent systematic reviews. It has been noted that game-based pedagogical approaches involving the simulation of competitive situations create more favorable conditions for the development of tactical thinking than traditional instruction focused primarily on the isolated acquisition of technical skills. At the same time, researchers highlight substantial heterogeneity in the methods used and the insufficient development of approaches to the comprehensive organization of the training process [15].

Analysis of the studies reviewed shows that a number of published studies focus primarily on the effectiveness of individual training tools, including small-sided games, game-based tasks, or exercises aimed at developing specific components of technical and tactical preparedness. The present study focuses on the pedagogical conditions that ensure the systematic use of game-based exercises within the structure of the training process. Within the developed model, game-based exercises are considered not in isolation but as a means of implementing a set of pedagogical conditions aimed at integrating technical and tactical training in young football players.

Certain limitations of the study should also be considered when interpreting the results obtained. The pedagogical experiment was conducted at a single sports organization and involved a relatively small sample of football players aged 8–10 years undergoing initial sports training. The experimental program lasted 8 months. In addition, the participants were assigned to the groups within the existing organization of the training process, which limited the possibility of fully controlling baseline differences between the groups. Therefore, the generalization of the findings to athletes of other age categories and stages of long-term athletic development requires further experimental verification.

Overall, the findings are consistent with the view that the pedagogical conditions under which game-based exercises are applied are important for integrating technical and tactical training.

Conclusion

The study showed that the systematic use of game-based exercises within the developed pedagogical model was associated with more pronounced positive dynamics in the technical and tactical preparedness of young football players aged 8–10 years compared with the traditional organization of the training process.

The practical significance of the study lies in the potential use of the developed pedagogical model in organizing the training process at the initial stage of football training. The proposed approach can be used by coaches in youth sports schools and football academies when planning training sessions aimed at the comprehensive improvement of athletes' technical and tactical preparedness.

The findings reflect the experience of implementing the pedagogical model within a single sports organization and do not claim universal applicability. Further research should assess the effectiveness of the proposed model at subsequent stages of long-term athlete development, as well as examine its application among football players of different age categories and levels of sports qualification.

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Effects of Tai Chi Fan Training on Impulsivity and Inhibitory Control in Patients with Substance Use Disorder: A Randomized Controlled Trial

This randomized controlled trial evaluated the effects of a 12-week Tai Chi Fan (TCF) program on impulsivity and inhibitory control among individuals with substance use disorder (SUD). Methods: Forty male patients undergoing compulsory rehabilitation were randomly assigned to either a TCF intervention group (n = 20; 60 min/session, 3 sessions/week) or a control group (n = 20) receiving routine care. Impulsivity and inhibitory control were assessed using the Barratt Impulsiveness Scale (BIS-11) and the Stroop task, respectively. Results: Compared with the control group, the TCF intervention group showed a significant reduction in total BIS-11 scores ($p < 0.001$). Furthermore, the intervention group demonstrated significantly shorter reaction times and higher accuracy in the Stroop incongruent condition, with significant group $\times$ time interactions ($p < 0.001$). Conclusion: A 12-week TCF program was associated with reduced impulsivity and improved inhibitory control among male patients with SUD undergoing compulsory rehabilitation. As a structured mind-body exercise, TCF may represent a potential non-pharmacological adjunct to addiction rehabilitation.

Keywords: Tai Chi Fan, substance use disorder, impulsivity, inhibitory control, randomized controlled trial.

Introduction

Substance use disorder (SUD) is a chronic relapsing condition characterized by persistent drug-seeking behavior and a high risk of relapse, posing a major challenge to global public health systems [1]. Although advances in pharmacological and psychological treatments have improved detoxification outcomes, many individuals continue to struggle with maintaining long-term abstinence after withdrawal. This phenomenon suggests that addiction is not solely driven by physiological dependence but is also closely associated with impairments in cognitive and behavioral regulation [2]. Consequently, understanding and intervening in addiction from a cognitive perspective has become an important direction in recent research [3].

Among the cognitive dysfunctions observed in SUD, impulsivity and deficits in inhibitory control have been identified as core features contributing to maladaptive decision-making and relapse vulnerability [4]. Individuals with SUD often exhibit heightened sensitivity to reward-related stimuli and reduced capacity to suppress inappropriate or prepotent responses. This imbalance between bottom-up impulsive drives and top-down executive control increases the likelihood of compulsive drug-seeking behaviors [5]. Therefore, interventions targeting impulsivity and the restoration of inhibitory control mechanisms are considered critical for improving rehabilitation outcomes [6].

Traditional rehabilitation approaches primarily rely on pharmacotherapy and psychological interventions. While these strategies are effective in alleviating withdrawal symptoms and emotional distress, their

impact on restoring executive function remains limited [7]. In recent years, physical exercise has emerged as a promising non-pharmacological intervention due to its accessibility, sustainability, and broad cognitive benefits [8]. Accumulating evidence suggests that regular exercise can improve mood, enhance neuroplasticity, and facilitate cognitive control processes [9]. Furthermore, mind–body exercises that integrate motor control and attentional regulation have demonstrated particular advantages in improving executive functions [10].

Among these approaches, Tai Chi has been widely applied across different populations due to its moderate intensity, rhythmic movement patterns, and long-term adherence potential, showing beneficial effects on cognitive function [11]. However, most existing studies have focused on traditional barehanded Tai Chi and general cognitive outcomes, with relatively limited attention to specific domains such as impulsivity and inhibitory control [12, 13]. Recent meta-analytic evidence further highlights that traditional health-preserving exercises significantly improve the overall mental health of individuals with SUD, establishing a psychological foundation for cognitive recovery [14]. Additionally, systematic reviews on aerobic exercise (AE) have confirmed its efficacy in enhancing inhibitory control among methamphetamine addicts [15].

Crucially, it should be emphasized that TCF is not merely a form of physical exercise, but rather a sophisticated “dual-task processing” activity. While traditional barehanded Tai Chi primarily focuses on internal energy (Qi) and center-of-gravity regulation through symmetrical body displacements, TCF introduces asymmetrical instrument manipulation and complex rhythmic shifts. These characteristics impose multiple cognitive challenges. First, the requirement for precise motor inhibition during rapid transitions may repeatedly engage neural mechanisms underlying response inhibition [16]. Second, the alternation between slow, continuous movements and fast, explosive actions demands flexible switching of motor programs, thereby recruiting cognitive processes related to conflict monitoring [16]. This complexity requires practitioners to allocate significantly more attentional resources for error detection and real-time correction, a process that is conceptually aligned with the conflict adaptation mechanisms observed in formal cognitive control training [16].

However, empirical research on the application of TCF in individuals with SUD remains limited [17]. To address this gap, the present study conducted a randomized controlled trial to systematically evaluate the effects of a 12-week standardized TCF training program on impulsivity and inhibitory control. It was hypothesized that TCF training would significantly reduce trait impulsivity, as measured by the Barratt Impulsiveness Scale (BIS-11), and improve conflict inhibitory control, as assessed by the Stroop task [18]. Following CONSORT guidelines, this study aims to provide rigorous empirical evidence for a standardized, scalable, and non-pharmacological cognitive rehabilitation strategy for individuals with SUD [19].

Methods and Materials

This study was designed as a single-center, parallel-group randomized controlled trial with a 1:1 allocation ratio, conducted in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines [19]. The intervention period lasted 12 weeks, with baseline assessments completed within one week prior to the intervention and post-intervention assessments conducted within one week after completion.

The study was carried out in a compulsory drug rehabilitation center operating under a closed management system, where participants lived in a controlled and stable environment throughout the study period, minimizing potential external confounding factors.

A total of 47 male patients diagnosed with substance use disorder (SUD) according to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-5) criteria were initially recruited. Participants were required to meet the following inclusion criteria: (1) diagnosis of SUD based on DSM-5; (2) aged 18–50 years; (3) in a stable detoxification phase; (4) physically capable of participating in exercise training; and (5) provision of written informed consent. Exclusion criteria included: (1) severe physical illness or contraindications to exercise; (2) comorbid severe psychiatric disorders or cognitive impairment; (3) recent participation in other structured exercise programs; and (4) any condition that could interfere with study completion.

Eligible participants were randomly assigned to either the Tai Chi Fan group or the control group using a random number table, with allocation performed by an independent researcher not involved in the intervention to minimize selection bias. Outcome assessments were conducted by blinded evaluators to reduce measurement bias.

Participants in the intervention group received standardized Tai Chi Fan training in addition to routine rehabilitation. The training program was conducted three times per week, with each session lasting approxi-

mately 60 minutes over a 12-week period. The intervention followed a progressive structure, including basic movement acquisition (weeks 1–4), combination training (weeks 5–8), and full routine practice (weeks 9–12). Training emphasized precise control of fan movements (e.g., opening, closing, and coordinated sequences), motor sequencing, rhythm regulation, and integration of breathing with movement. During the final stage, participants practiced a standardized 16-form routine for 2-3 repetitions per session, with 2-3-minute rest intervals, and performed tempo variation exercises involving transitions between slow and fast movements. Exercise intensity was maintained at a moderate level (rating of perceived exertion, RPE = 11–13), with continuous emphasis on movement accuracy and coordination.

The control group participated only in routine rehabilitation activities, including daily labor, basic physical training, and standard educational programs, without additional structured exercise intervention. The duration and frequency of activities were comparable between groups.

Impulsivity was assessed using the Barratt Impulsiveness Scale, version 11 (BIS-11), a 30-item self-report questionnaire measuring attentional, motor, and non-planning impulsivity, with higher scores indicating greater impulsivity. Inhibitory control was evaluated using a computerized Stroop task, which included congruent, neutral, and incongruent conditions. Reaction time and accuracy under incongruent (conflict) conditions were recorded as primary indicators of inhibitory control performance.

Statistical analyses were performed using SPSS version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation (mean $\pm$ SD). A two-way repeated-measures analysis of variance (ANOVA) was conducted with group (Tai Chi Fan vs. control) as the between-subject factor and time (pre- vs. post-intervention) as the within-subject factor to examine main and interaction effects. When significant interaction effects were observed, simple effects analyses were performed. A p -value < 0.05 was considered statistically significant.

Outcome Measures

Impulsivity: The Barratt Impulsiveness Scale, version 11 (BIS-11), was used to assess individual impulsivity. The scale consists of 30 items divided into three dimensions: attentional, motor, and non-planning impulsivity. Higher total scores indicate higher levels of impulsivity.

Inhibitory Control: A computerized color-word Stroop task was employed to evaluate inhibitory control. The task included congruent, neutral, and conflict (incongruent) conditions. Reaction time (RT) and accuracy under conflict conditions were recorded to reflect inhibitory control performance.

Statistical Analysis Data were analyzed using SPSS 26.0 and expressed as Mean $\pm$ Standard Deviation (M $\pm$ SD). A 2 (Group: TCF vs. Control) $\times$ 2 (Time: Pre vs. Post) repeated-measures analysis of variance (ANOVA) was performed to examine group, time, and interaction effects. Simple effects were analyzed if interaction effects were significant. The significance level was set at $p < 0.05$.

Results and Discussion

Participant Flow The recruitment and screening process strictly followed CONSORT guidelines. Out of 47 potential participants, 4 were excluded and 43 were randomly assigned to either the TCF group ($n=21$) or the control group ($n=22$). During the intervention, 1 participant in the TCF group and 2 in the control group dropped out due to non-study related reasons. Ultimately, 40 participants (20 per group) completed all assessments and were included in the analysis.

Baseline Characteristics At baseline, no significant differences were observed between the two groups in terms of age, education, drug use history, BIS-11 scores, or Stroop reaction times ($p > 0.05$), indicating good comparability between the groups (Table 1).

Table 1

Comparison of baseline characteristics between groups (M $\pm$ SD)

Indicator	TCF Group (n=20)	Control Group (n=20)	t	p
Age (years)	34.67 $\pm$ 6.82	35.12 $\pm$ 7.15	0.231	0.818
Education (years)	9.26 $\pm$ 2.15	8.92 $\pm$ 2.33	0.568	0.572
Drug Use History (years)	6.89 $\pm$ 3.24	7.15 $\pm$ 3.51	0.287	0.775
BIS-11 Total Score	76.41 $\pm$ 7.46	76.53 $\pm$ 6.67	-0.070	0.945
Stroop RT (ms)	923.86 $\pm$ 84.85	913.86 $\pm$ 98.93	0.764	0.448

Effects on Impulsivity (BIS-11) Post-intervention, total BIS-11 scores and all sub-dimension scores in the TCF group decreased significantly compared to baseline ($p < 0.001$). Repeated-measures ANOVA revealed significant group $\times$ time interaction effects for the total score and all dimensions ($p < 0.001$), as detailed in Table 2. No significant changes were observed in the control group.

Table 2

Comparison of BIS-11 scores before and after intervention (M $\pm$ SD)

Indicator	Time	TCF Group (n=20)	Control Group (n=20)	F	p
BIS-11 Total	Pre	76.41 $\pm$ 7.46	76.53 $\pm$ 6.67	28.65	<0.001
	Post	62.30 $\pm$ 7.20	77.20 $\pm$ 7.80		
Attentional	Pre	28.31 $\pm$ 2.84	28.16 $\pm$ 2.53	22.37	<0.001
	Post	22.90 $\pm$ 2.70	28.40 $\pm$ 3.00		
Motor	Pre	28.22 $\pm$ 2.76	28.41 $\pm$ 2.43	25.89	<0.001
	Post	23.10 $\pm$ 2.80	28.65 $\pm$ 2.90		
Non-planning	Pre	19.88 $\pm$ 1.92	19.97 $\pm$ 1.78	18.72	<0.001
	Post	16.30 $\pm$ 1.90	20.15 $\pm$ 2.10		

Effects on Stroop Task Performance The TCF group showed significantly shortened reaction times and improved accuracy after the 12-week intervention ($p < 0.001$). ANOVA results indicated significant group $\times$ time interactions for both reaction time and accuracy ($p < 0.001$), demonstrating that TCF training effectively enhances conflict inhibitory control, as shown in Table 3.

Table 3

Comparison of Stroop task performance before and after intervention (M $\pm$ SD)

Indicator	Time	TCF Group (n=20)	Control Group (n=20)	F	p
RT (ms)	Pre	923.86 $\pm$ 84.85	913.86 $\pm$ 98.93	48.23	<0.001
	Post	730.00 $\pm$ 70.00	868.00 $\pm$ 68.00		
Accuracy (%)	Pre	87.00 $\pm$ 5.00	86.00 $\pm$ 4.00	36.89	<0.001
	Post	94.00 $\pm$ 3.00	88.00 $\pm$ 5.00		

This study employed a randomized controlled trial design to systematically examine the intervention effects of Tai Chi Fan (TCF) training on impulsivity and inhibitory control in patients with substance use disorder (SUD). The results indicated that 12 weeks of TCF training significantly reduced impulsivity levels and markedly improved conflict inhibitory control, with significant group $\times$ time interaction effects observed across all indicators; this suggests that the intervention effects are specific rather than being caused by simple temporal changes or routine rehabilitation factors [20]. Previous research suggests that increased impulsivity and impaired inhibitory control are critical cognitive phenotypes of substance use disorders and important factors influencing relapse risk [21]. Therefore, the results of this study provide behavioral empirical support for the application of TCF training in addiction-related cognitive rehabilitation [22].

The Ameliorative Effect of TCF on Impulsivity and Its Potential Mechanisms

This study found that post-intervention, the total BIS-11 score in the TCF group was significantly lower than that at baseline, with all dimensions showing a consistent trend of improvement, while no significant changes were observed in the control group. This suggests that TCF training has a relatively stable overall regulatory effect on impulsivity [23]. As a key psychological and behavioral feature of addictive behavior, impulsivity is closely linked to immediate reward preference, insufficient behavioral control, and elevated relapse risk [24]. Therefore, lowering impulsivity levels is of great significance for addiction rehabilitation [25].

From the perspective of potential mechanisms, TCF training is characterized by continuous motor sequences, rhythmic changes, and instrument manipulation. During practice, the continuous requirement for motor memory, attention maintenance, and behavioral regulation may repeatedly activate prefrontal-anterior cingulate cortex-related neural networks [26]. Existing studies have shown that the prefrontal cortex plays a

vital role in impulse control, goal maintenance, and behavioral regulation, yet individuals with addiction generally exhibit prefrontal functional abnormalities and decreased executive control capacity [27]. Through the continuous practice of “motor control—attentional regulation—behavioral inhibition”, TCF training may promote the recovery of prefrontal-related functions to a certain extent, thereby reducing impulsive response tendencies [28].

Furthermore, TCF training emphasizes movement rhythm, breathing coordination, and focused attention, exhibiting distinct mind–body integration characteristics [29]. This is consistent with recent findings that traditional exercises not only target cognitive domains but also effectively mitigate psychological distress in addicted populations, suggesting that the TCF-induced reduction in impulsivity may be partially mediated by improvements in overall mental health and self-regulation [14]. Previous research has shown that mind–body exercise can improve executive function and enhance cognitive control capacity [30]. For individuals with substance addiction, impulsive behavior is often associated with negative emotions, drug craving, and poor self-control; TCF training may indirectly improve impulsivity performance by enhancing emotional regulation and self-efficacy [31]. Existing research on Tai Chi and related mind–body exercises has also found positive effects on attentional bias, drug craving, and cognitive control in addicted populations [32].

Regarding training characteristics, the practice of TCF requires constant inhibition of incorrect movements, adjustment of tempo, and execution of established motor patterns; this repeated “inhibition–execution” process may produce a certain transfer effect [33]. Prior research has pointed out that inhibitory control training can improve addiction-related behavioral control capacity [34]. Thus, TCF training is not merely physical activity but rather a comprehensive intervention modality that combines physical practice with cognitive control training [35].

The Ameliorative Effect of TCF on Conflict Inhibitory Control and Its Potential Mechanisms

In terms of inhibitory control, this study utilized the color-word Stroop task and found that TCF training significantly shortened reaction times and increased accuracy, demonstrating that it effectively enhances an individual’s cognitive control capacity in conflict situations [18]. The Stroop task is a classic paradigm for evaluating inhibitory control and conflict monitoring; performance typically reflects an individual’s ability to inhibit prepotent responses and maintain goal-directed tasks under interference [9]. Mechanistically, conflict inhibition relies primarily on the synergistic effect of the prefrontal and parietal attention networks [27]. Due to its motor complexity and instrument manipulation requirements, TCF training requires practitioners to process multi-dimensional information—such as motor execution, fan positioning, rhythm control, and attention allocation—simultaneously. This multi-dimensional processing may enhance the functional integration of the prefrontal-parietal network, thereby improving conflict processing efficiency [26]. It is noteworthy that compared to traditional empty-hand Tai Chi, TCF adds the element of instrument operation, which places higher demands on attentional control, motor inhibition, and spatial coordination; this may be a key reason for the significant improvement in inhibitory control observed in this study [16].

Practical Significance of TCF in Addiction Rehabilitation

From a practical application perspective, TCF training is characterized by high safety, moderate intensity, ease of implementation, and low cost, making it suitable for promotion in compulsory detoxification facilities and community rehabilitation settings [8]. The 12-week duration and moderate intensity employed in our protocol align with proposed dose-response models in recent meta-analyses, which indicate that interventions lasting at least four weeks with moderate frequency are optimal for eliciting neurocognitive gains in individuals with SUD [36]. While aerobic exercise provides general benefits [15], TCF’s unique dual-task nature may offer a more specialized path for conflict adaptation. Currently, addiction rehabilitation still faces challenges such as insufficient treatment adherence, unstable long-term effects, and inadequate recovery of cognitive functions [7]. Compared to pure pharmacotherapy or traditional psychological interventions, exercise intervention has better acceptability and sustainability, and has been recognized as a potential adjunctive intervention in addiction rehabilitation [35]. Based on the results of this study, TCF training could be considered a supplement to routine rehabilitation programs, combined with psychological intervention and health education to form a multi-dimensional “physiological detoxification—psychological correction—exercise-based cognitive rehabilitation” intervention model [36].

Conclusion

Standardized 12-week Tai Chi Fan training significantly reduces impulsivity and enhances conflict inhibitory control in individuals with substance use disorder. As a safe, sustainable, and low-cost non-

pharmacological intervention, Tai Chi Fan serves as an effective adjunctive strategy for cognitive rehabilitation in addiction recovery systems.

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