MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
HRYHORII SKOVORODA UNIVERSITY IN PEREIASLAV

THEORY and PRACTICE
of Physical Culture and Sports

Scientific and practical journal

Vol. 5, No. 1
2026

Pereiaslav
2026

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
УНІВЕРСИТЕТ ГРИГОРІЯ СКОВОРОДИ В ПЕРЕЯСЛАВІ

ТЕОРІЯ і ПРАКТИКА
фізичної культури і спорту

Науково-практичний журнал

Том 5, № 1
2026

Переяслав
2026

ISSN 2786-6432
UDC 796 e-ISSN 2786-6424

Founder:
Hryhorii Skovoroda University in Pereiaslav

Year of foundation: 2022

Frequency: semi-annual

Recommended for printing and distribution via the Internet by the Academic Council of Hryhorii Skovoroda University in Pereiaslav
(Minutes No. 10 of May 12, 2026)

Media identifier: R30-04681
(Decision of the National Council of Television and Radio Broadcasting of Ukraine No. 1442, Minutes No. 14 of April 25, 2024)

The journal is included in the List of Professional Scientific Publications of Ukraine (Category "B"). Specialties:
0114 Teacher training with subject specialisation; 1014 Sports
(Order of the Ministry of Education and Science of Ukraine No. 928 of 11 June 2026).

Cluster – Human capital development, social sciences and journalism.

The journal is presented in the following scientometric databases, repositories and scientific systems:
Crossref; Professional Publications of Ukraine; UCSB Library; Google Scholar; Vernadsky National Library of Ukraine; Dimensions; University of Oslo Library; University of Hull Library; Open Ukrainian Citation Index (OUCI); Litmaps; ERIH PLUS

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ISSN 2786-6432
УДК 796 e-ISSN 2786-6424

Засновник:
Університет Григорія Сковороди в Переяславі

Рік заснування: 2022

Періодичність випуску: двічі на рік

Рекомендовано до друку та поширення
через мережу Інтернет Вченою радою
Університету Григорія Сковороди в Переяславі
(протокол № 10 від 12 травня 2026 року)

Ідентифікатор медіа: R30-04681
(Рішення Національної ради України з питань телебачення і радіомовлення
№ 1442, протокол № 14 від 25 квітня 2024 року)

Журнал включено
до Переліку наукових фахових видань України (Категорія «Б»). Спеціальності:
А4 Середня освіта (за предметними спеціальностями); А7 Фізична культура і спорт
(наказ Міністерства освіти і науки України № 928 від 11.06.2026).

Кластер: Розвиток людського капіталу, соціальні науки та журналістика.

Журнал представлено
у таких наукометричних базах даних, репозитаріях та пошукових системах:
Crossref; Фахові видання України; UCSB Library; Google Академія;
Національна бібліотека України імені В.І. Вернадського; Dimensions;
University of Oslo Library; University of Hull Library;
Open Ukrainian Citation Index (OUCI); Litmaps; ERIH PLUS

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ЗМІСТ

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 13.01.2026.Revised: 14.04.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.011.3:159.947.5-053.6
DOI: 10.69587/tppcs/1.2026.09

Forming motivation for physical education in adolescence

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Abstract. The decline in physical activity among adolescents in the context of digitalisation and increasing academic workload highlights the need to understand the mechanisms of forming sustainable motivation for systematic physical education in the 11-18 age group. The aim of the study was to identify and summarise the psychological determinants, sociocultural influences and pedagogical tools that contribute to the development of adolescents' motivation for physical education and sports activities, taking into account modern digital tools. The research was carried out through a systematic analysis of 43 peer-reviewed publications for the period 2015-2025 from international databases using content analysis, thematic systematisation and comparative comparison of the effectiveness of various pedagogical technologies. Analysis of psychological factors found that intrinsic motivation was a key predictor of daily physical activity among adolescents, with the satisfaction of basic psychological needs mediating approximately 25% of the influence of parental support on activity levels. Gender differences manifested themselves in the fact that boys demonstrated a higher orientation towards the perception of physical competence and competitiveness, while girls valued aesthetic aspects and social interaction to a greater extent. The study of sociocultural factors revealed a hierarchical structure of influences, where the family environment played the role of the primary agent of socialisation through the mechanisms of parental expectations and behaviour modelling, while peer support and digital forms of interaction created additional channels of motivational influence. Analysis of pedagogical technologies showed that gamified interventions based on self-determination theory lasting more than 12 weeks increased moderate-intensity physical activity, with group training having a stronger effect than individual forms. The results made it possible to develop a three-level system of recommendations for teachers, coaches and organisers of physical education and sports activities, covering individual pedagogical interaction, the organisation of the educational process and systemic policies with an emphasis on supporting the autonomy, competence and social belonging of adolescents. The practical significance lies in creating an evidence base for the development of effective programmes to increase physical activity among young people, taking into account age, gender and cultural characteristics

Keywords: basic psychological needs; self-determination; goal setting; gamification; autonomy; digital tools

Introduction

Adolescence is a critical period for forming healthy habits, but it is precisely at this time that there is a significant decline in physical activity due to increasing academic demands, preoccupation with digital technologies, and changing priorities. Understanding the mechanisms of motivation for physical activity at this age is important for

Suggested Citation: Panhelova, N., Shapran, O., & Kravchenko, T. (2025). Forming motivation for physical education in adolescence. *Theory and Practice of Physical Culture and Sports*, 5(1), 9-23. doi: 10.69587/tppcs/1.2026.09.

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preventing physical inactivity and ensuring the harmonious physical and mental development of young people. L.I. Rak *et al.* (2024) conducted a comprehensive study aimed at determining the level of physical activity of adolescents in the critical conditions of military conflict and developing strategies to optimise and increase physical activity during a period of social crisis. The results of the survey showed a decrease in the level of physical activity of adolescents in wartime compared to the quarantine period: 70.9% of adolescents demonstrated a low level of physical activity, 16.5% demonstrated an average level, while only 12.6% demonstrated a high level of activity. The researchers found that intrinsic desire was the main motivating factor for increasing physical activity, as indicated by 87% of children with low activity and 93% of children with high activity.

G.H. Malchrowicz-Mośko *et al.* (2020) conducted a study aimed at identifying motivational factors in Polish children and adolescents aged 12 who participated in running competitions as part of the "On the Way to the Marathon" project in Poznań. The results of the study revealed that the greatest motivators for completing the distance were the immediate feelings of satisfaction and entertainment during participation in a mass competition, reaching an average score of 6.01 out of 7 points, while the motives of social affiliation and the desire to be in the company of peers showed significantly lower scores of 3.96 out of 7 points. I. Soós *et al.* (2019) conducted a large-scale comparative study aimed at investigating the impact of perceived autonomous support from parents, teachers and peers on the development of motivation among young people in the context of physical education and leisure-time physical activity. The results of the study showed that perceived autonomous support from family and peers was associated with higher levels of autonomous motivation for leisure-time physical activity in all four countries studied, but the nature of the influence of physical education teachers varied depending on the geographical region. The study also found statistically significant gender differences: boys reported higher levels of physical activity and perceived more support and freedom of choice from teachers, while girls showed higher levels of autonomous motivation in the context of formal physical education.

I. Harbichová *et al.* (2025) conducted a study at Charles University in Prague aimed at identifying and classifying motivational profiles among Czech young people studying physical education teacher training and sports coaching programmes. The results of the analysis revealed the existence of four distinct motivational profiles among the respondents: a group with moderately autonomous motivation (51.5% of the total sample), a group with combined controlled and amotivated motivation (21.9%), a group with low motivation for sports activities (19.1%), and a group with predominantly amotivated motivation (7.5%). The study by H. Butenko (2025) involved 40 sixth-grade students who were systematically divided into control and experimental groups. The results of the study showed that the introduction of a comprehensive system of physical education and recreational activities contributed to a statistically significant increase in the level of motivation of schoolchildren to engage in physical education, especially in the context of recreational activities. The students in the experimental group showed a significant improvement in physical fitness indicators and an increase in positive attitudes and emotional involvement in physical activity compared to the control group.

S.V. Hryshchenko *et al.* (2024) conducted a systematic analysis of scientific literature aimed at studying various aspects of physical activity among Ukrainian adolescents aged 11-14 as a component of a healthy lifestyle. The researchers found that there is a trend towards a deterioration in the health indicators of adolescents in this age group in Ukraine, while the formation of basic values regarding a healthy lifestyle remains a critically important task. The scientists concluded that maintaining the health of Ukrainian adolescents aged 11-14 in wartime appears to be an effective form of both prevention and health promotion for young people. K. Frömel *et al.* (2025) conducted a comparative study of the impact of the COVID-19 pandemic on the physical activity patterns of Czech and Polish adolescents in different segments of the school day. The results of the study showed that both Czech and Polish boys and girls demonstrated statistically significantly lower transport-related physical activity to and from school after pandemic restrictions compared to the pre-pandemic period. The study found that the COVID-19 pandemic disrupted regular physical activity habits on school days, which was particularly evident in reduced activity during commutes to school.

C. Cefai *et al.* (2025) conducted a large-scale global study aimed at investigating the association between physical activity levels and life satisfaction in 15-year-old adolescents from 64 countries around the world. The researchers analysed data from the 2022 Programme for International Student Assessment, which covered 399,794 15-year-old students. The results of the study showed that even after controlling for these multilevel factors, physical activity remained positively and statistically significantly associated with students' overall life satisfaction. An analysis of gender differences in the magnitude of this association showed that gender disparities did not reach statistical significance in most countries (55 out of 64), indicating the universality of the effect regardless of gender. Despite their value, the above-mentioned studies have certain limitations: most of them focus on specific contexts (armed conflict, the COVID-19 pandemic) or specific age groups, which makes it difficult to generalise the results to the wider adolescent population. In addition, some of the studies were conducted in individual countries, which limits the possibility of extrapolating the conclusions to other cultural and socio-economic contexts. The aim of the study was to systematise the psychological, sociocultural and pedagogical factors that shape motivation to engage in physical culture in adolescence.

Materials and Methods

The presented study was review-analytical and aimed at systematising and critically analysing scientific publications devoted to psychological, sociocultural and pedagogical factors influencing the formation of adolescents' motivation to engage in regular physical activity. The study was conducted during 2024-2025 based on leading international scientometric databases. A systematic literature search was conducted in PubMed/MEDLINE, Web of Science Core Collection, Scopus, PsycINFO, SPORTDiscus and ERIC databases using search queries in English:

"adolescent motivation AND physical activity", "self-determination theory AND youth sport", "gamification AND adolescent exercise" and other combinations of key terms with Boolean operators. The inclusion criteria involved the selection of peer-reviewed articles mainly from 2019-2025 (some works from 2015-2018 were included if they were methodologically relevant) with empirical data on the motivational mechanisms of physical activity in adolescents aged 11-18 (studies with samples that partially covered the age of 10 or 19-20 were allowed if the majority of respondents corresponded to the target range), valid psychometric instruments, and publication in journals with an impact factor. Exclusion criteria included publications about adults or preschoolers, studies without clear methodology, duplicate works, and non-peer-reviewed materials. The initial search identified 247 publications, of which 103 were selected for full-text analysis, and 43 sources that most closely met the objectives and quality criteria were ultimately included in the systematic analysis. An additional 8 sources were included in the introduction to contextualise the research topic.

The methodological basis was a content analysis of scientific publications using the principles of systematic review, which ensured a structured approach to the selection and synthesis of empirical data. Each publication was analysed according to the following parameters: sample characteristics, methodological design, theoretical framework, psychometric instruments, statistical methods, and practical implications. Thematic analysis was used to systematise motivational factors according to their nature into internal psychological determinants, sociocultural factors and pedagogical means, with an assessment of empirical validity based on the number of studies and the magnitude of effects. Comparative analysis was used to compare the effectiveness of traditional and innovative pedagogical technologies, gender-specific features of the perception of motivational stimuli, and the effectiveness of individual and group forms of classes depending on the basic motivational level of participants. Zotero (version 7.0.11) and Microsoft Excel 2021 (version 2405) software was used to systematise the data.

The results were interpreted through the prism of Edward Deci and Richard Ryan's self-determination theory (Ryan & Deci, 2017), which allowed to integrate empirical data into a conceptual model of forming sustainable motivation through the satisfaction of basic psychological needs for autonomy, competence, and social belonging. The analysis included the identification of causal relationships, mediating mechanisms, and moderators of the effectiveness of motivational interventions, while a critical analysis of methodological limitations allowed to formulate directions for further research. Attention was paid to identifying contradictions between different studies and gaps in the existing scientific base in order to determine priority areas for future empirical research. The synthesis of results was aimed at developing a set of scientifically based practical recommendations for teachers, coaches, parents, and organisers of physical education and sports activities. The recommendations were structured according to three levels of intervention: the micro level of individual pedagogical interaction, the meso level of educational process organisation, and the macro level of systemic policies, with a particular focus on vulnerable groups of adolescents. Each recommendation was accompanied by references to specific empirical studies confirming its effectiveness, with a description of the expected results and possible limitations of application.

Results and Discussion

Psychological factors and internal determinants of adolescents' motivation for physical activity

The motivation of adolescents to engage in physical activity was shaped by a complex interaction of internal and external factors, as confirmed by numerous scientific studies. H. Kalajas-Tilga *et al.* (2020) demonstrated in a longitudinal study of 397 adolescents aged 11-15 that internal motivation for physical education was the only significant motivational predictor of daily physical activity measured objectively ($\beta = 0.29$; $p = 0.009$), while identified regulation, introjected regulation, and external regulation did not show statistically significant associations with activity levels. The satisfaction of basic psychological needs positively predicted intrinsic motivation ($\beta = 0.86$; $p = 0.001$), which mediated the relationship between perceived autonomy support from physical education teachers and objectively measured moderate- and high-intensity activity. The self-determination theory of R.M. Ryan & E.L. Deci (2017) postulated three basic psychological needs – autonomy, competence, and social belonging – as fundamental to the development of quality motivation.

Data on the relationship between internal and external motivation among adolescents was presented by M.E. Işıkgöz (2025) in a study of 1,399 Turkish high school students, where the average internal motivation score was 5.68 ($SD = 1.51$) on a seven-point scale, identified regulation – 5.77 ($SD = 1.22$), introjected regulation – 4.13 ($SD = 1.74$), and external regulation – 3.69 ($SD = 1.68$), which indicated the predominance of autonomous forms of motivation over controlled ones. Internal motivation showed a strong positive correlation with positive emotions of achievement ($\beta = 0.63$; $p < 0.001$) and a negative correlation with negative emotions ($\beta = -0.68$; $p < 0.001$), while external motivation showed only a weak correlation with positive emotions ($\beta = 0.07$; $p < 0.001$) and did not correlate significantly with negative emotions. R.K. Dishman *et al.* (2018) tracked 260 adolescents from grades 6 to 9 and found an annual decline in all forms of motivation, including intrinsic motivation (-0.100 units per year), integrated regulation (-0.138), identified regulation (-0.104), introjected regulation (-0.089), and external regulation (-0.095). Physical activity declined less in adolescents who maintained higher levels of intrinsic motivation or integrated regulation, but only if they maintained a high level of enjoyment goals compared to other students, confirming the interaction between the quality of motivation and the content of goals as a modifier of the effect. R. de Oliveira Barbosa *et al.* (2024) surveyed 553 Brazilian adolescents aged 12-15 and found that autonomous motivation mediated 25% of the association between parental support and physical activity, 38% of the relationship between the satisfaction of basic psychological needs by peers, 83% by teachers, and 70% between the perception of the environment and activity. Autonomy, competence, and relatedness, which formed the core of self-determination theory, influenced motivation by creating an environment

that satisfied these needs: support for autonomy by physical education teachers positively predicted the satisfaction of psychological needs (β = 0.81; $p = 0.001$), which in turn strengthened intrinsic motivation and indirectly increased the levels of physical activity among adolescents aged 12-17.

Gender differences in body perception were found to be significant predictors of motivational attitudes. K. Sick *et al.* (2025) in a longitudinal study of Canadian adolescents ($n = 7,884$; 52.2% girls; mean age 14.4 years) demonstrated that a positive self-concept and perception of physical attractiveness in 9th grade predicted continued participation in physical education in 10th grade, predominantly among boys. For boys, each unit increase in global self-concept predicted a 4% increase in the likelihood of continuing physical education (*OR* = 1.04; 95% *CI*: 1.01-1.07; $p < 0.05$), while for girls this effect was statistically insignificant (*OR* = 1.02; $p > 0.05$). With regard to the perception of physical attractiveness, girls and boys showed gender differences: boys who reported the most positive perception of their own appearance were 12% more likely to continue physical education than their peers who expressed dissatisfaction with their appearance (*OR* = 1.12; 95% *CI*: 1.02-1.22; $p < 0.05$), while for girls this relationship remained statistically insignificant.

S. Pavlović *et al.* (2025), in a study of 398 pupils of secondary educational institutions aged around 10 years, identified gender differences in the relationship between physical self-concept and physical activity. Among boys, the highest levels of activity during physical education lessons were associated with higher perceived sports competence ($M = 3.86$, $SD = 0.47$ in the most active group compared with $M = 2.19$, $SD = 0.88$ in the low-activity group; $p = 0.01$), whereas gender differences were evident in that girls with the highest activity levels showed higher ratings of satisfaction with their physical appearance ($M = 3.94$, $SD = 0.61$ compared with $M = 3.12$, $SD = 0.39$ in the low-activity group; $p = 0.01$), with no significant differences in perceived sports competence. Intrinsic motivation was found to be strongly associated with activity: in the most active group, boys demonstrated a score of 5.29 ($SD = 0.39$) compared with 3.66 ($SD = 0.36$) in the low-activity group, while among girls the corresponding values were 5.11 ($SD = 0.13$) and 3.92 ($SD = 0.75$).

Fear of failure and achievement striving proved to be critical motivational factors in adolescent sport. M.J. Schmid *et al.* (2021), in a longitudinal study of 155 young individual-sport athletes (mean age 16.47 years), traced the relationship between motivational patterns and subsequent sporting success over a period of 2.5 years. Athletes with high intrinsic achievement motivation who simultaneously demonstrated low levels of fear of failure had twice the likelihood of competing at the international level compared with the control group (*OR* = 2.12; 95% *CI*: 1.03-4.33; $p < 0.05$). In contrast, athletes characterised as "fear-of-failure athletes" showed a significantly lower probability of reaching the highest level of competition (*OR* = 0.29; 95% *CI*: 0.11-0.82; $p < 0.05$). Mean fear-of-failure scores in the group of fear-of-failure athletes were 1.12 ($SD = 0.57$), whereas in the most successful group this indicator was only 0.14 ($SD = 0.22$), demonstrating a substantial difference in motivational profiles. Q. Hu *et al.* (2023), in a study examining the impact of coaching style on fear of failure in 252 active athletes, found that a controlling coaching style was negatively correlated with satisfaction of basic psychological needs ($r = -0.356$; $p < 0.001$) and positively correlated with controlled attachment to sport ($r = 0.364$; $p < 0.001$), which in turn strongly predicted fear of failure (β = 0.28; $p < 0.001$). Satisfaction of basic psychological needs demonstrated a powerful protective effect against fear of failure (β = -0.36; $p < 0.001$), with this effect being mediated through a reduction in controlled attachment. The model showed that basic psychological needs and controlled attachment mediated 71.18% of the total effect of coaching style on fear of failure (95% *CI*: 0.395-0.899). Gender differences in the manifestation of fear of failure were also substantial. F. Ahmedov *et al.* (2025), in a study of 279 athletes aged 12-29 years, identified a strong positive correlation between pre-competition anxiety and fear of failure across all groups ($r > 0.50$); however, boys demonstrated higher levels of both pre-competition anxiety and fear of failure compared with girls, with psychological difficulties intensifying with age. The evidence points to a complex interaction between intrinsic and extrinsic motivational factors regulating adolescents' participation in physical activity, with different types of motivation exerting differentiated effects on behaviour and sport commitment. Below, in Table 1, a structured classification of the main motivational factors influencing adolescents' physical activity is presented, with an emphasis on their psychological content and methods of enhancement.

Table 1. Classification of motivational factors of adolescents' physical activity by psychological content

Type of motivation	Psychological basis	Manifestations in adolescents	Stability of the motive	Methods of enhancement
Intrinsic process-oriented	Enjoyment of the process	Joy derived from movement and play	High	Variety of exercises
Intrinsic outcome-oriented	Goal achievement	Improvement of performance	Moderate	Goal setting
Extrinsic social	Recognition by others	Approval from peers	Low	Group-based training
Extrinsic material	Rewards	Prizes, certificates	Very low	Reward systems
Health-related motivation	Concern for health	Disease prevention	Moderate	Educational programmes
Social-communicative	Communication	Friendship, team involvement	High	Team sports
Aesthetic	Physical beauty	Body shaping	Moderate-high	Fitness, dance

Source: developed by the authors based on research by D. M. Litt *et al.* (2011), J. Martins *et al.* (2021), L. Liu *et al.* (2025)

As a conclusion drawn from Table 1, there is a qualitative difference between intrinsic and extrinsic motives in terms of their stability and psychological consequences, since intrinsic process-oriented and social-communicative motivation show the highest stability precisely because they satisfy the fundamental psychological needs for autonomy, competence and relatedness. In contrast, extrinsic material motivation proves to be the least stable, as it does not

engage deep psychological mechanisms of self-regulation and is easily displaced when external conditions change. Equally important is the relationship between the type of motivation and adherence to participation: when adolescents are motivated by intrinsic factors (enjoyment of movement, attainment of competence, social interaction), they demonstrate a higher proportion of long-term engagement in physical activity and lower dropout rates from sport, whereas reliance on material rewards often leads to a phenomenon of "demoralisation", whereby the cessation of rewards causes a sharp decline in motivation even when initial interest was present. A further notable feature is that aesthetic and health-oriented motivation occupy an intermediate position, combining elements of intrinsic enjoyment with the pursuit of external outcomes. This indicates that the most effective programmes for promoting physical activity should integrate several types of motivation simultaneously, particularly taking into account the needs for competence and relatedness as key drivers of behavioural change in adolescents.

S.G. Goddard *et al.* (2025) presented a structured goal-setting approach based on the principles of specificity, measurability, attainability, relevance and time limitation. Goal specificity enabled adolescents to clearly understand the targeted aspects of sporting activity. Measurability ensured objective assessment of progress and the provision of positive feedback on achievements. Personalisation of goals on the basis of existing capabilities and individual interests was associated with increased intrinsic motivation among adolescents who set individual goals aimed at a 5-10% improvement relative to their own baseline, rather than normative benchmarks. K.R. Ylitalo *et al.* (2023), in a study of 151 adults, identified an association between self-regulatory strategies and physical activity levels at follow-up: each one-unit increase in a self-regulation strategy score was associated with an additional 20.5 MET-minutes (metabolic equivalent of task) of daily physical activity ($b = 20.5$; $SE = 9.8$; $p = 0.04$), after adjustment for age, sex and baseline physical activity levels. Self-monitoring of physical activity, goal setting and self-reward constituted the self-regulation strategies showing the greatest frequency of change from baseline to follow-up.

C.B. Phillips *et al.* (2020), in a study of 85 adults, identified a moderating role of delay discounting in the effectiveness of financial incentives for increasing physical activity. Delay discounting indices ranged from a log geometric mean k of -8.75 to -1.39 ($M = -4.93$; $SD = 1.60$). At the lowest levels of delay discounting, the difference in effect between immediate and delayed rewards amounted to 3,105 steps per day from baseline to the intervention phase ($b = 3,105$; $p = 0.004$), whereas at the highest levels this difference was 2,698 steps per day ($b = 2,698$; $p = 0.012$). Delay discounting indices were negatively correlated with age ($r = -0.32$ among younger individuals). S. van de van de Groep *et al.* (2023), in a neuroimaging study of 96 adolescents aged 10.16-20.21 years, identified age-related differences in temporal discounting of rewards. Younger adolescents demonstrated higher levels of delay discounting, whereas older adolescents showed a greater willingness to wait for larger delayed rewards. The area under the curve as a measure of temporal discounting was higher in older adolescents ($F(1,94) = 7.20$; $p = 0.009$; partial $\eta^2 = 0.07$), indicating lower impulsivity. Social context modified temporal discounting: when choices involved an immediate reward for a friend compared with a delayed reward for oneself, the area under the curve (AUC) was 0.52 ($SD = 0.24$), which was significantly lower than in conditions where rewards concerned only the individual (AUC = 0.58; $SD = 0.25$; $p = 0.002$). Activation in the subgenual anterior region and the ventral striatum was positively correlated with impulsivity in the choice of immediate rewards.

J.B. Courtney *et al.* (2021) conducted a longitudinal study of a nationally representative sample of 2,785 American adolescents from 11th grade to four years after graduation to determine the dynamics of physical activity and the role of motivation in its planning. Physical activity decreased by 0.31 days per week from 11th grade to the first year after graduation ($b = -0.31$; $\beta = -0.22$; $p < 0.001$), but did not change significantly from the first to the fourth year after graduation ($b = -0.08$; $\beta = -0.04$; $p = 0.052$). Autonomous motivation was positively associated with physical activity throughout the study period ($b = 0.23$-0.33; $\beta = 1.90$-4.37; $p < 0.001$). Planning physical activity directly correlates with its implementation ($b = 0.44$; $\beta = 0.21$; $p < 0.001$) with individual variability of the effect. R.K. Dishman *et al.* (2018) in a prospective study of 187 adolescents from grades 5 to 11 established the modifying role of self-efficacy in relation to changes in goals and beliefs about the necessity of physical activity. Physical activity was more limited in students who had decreased self-efficacy and: retained limiting beliefs about physical activity, were not sufficiently motivated to improve their physical fitness, or had improved body composition and expanded social circles. The interaction between changes in self-efficacy and changes in the perception of limiting factors was significant ($z = 4.30$; $p < 0.001$), as was the interaction between changes in self-efficacy and goals for improving appearance ($z = 10.63$; $p < 0.001$). Students with greater declines in self-efficacy and low motivation to improve physical fitness showed greater declines in physical activity. A. Deng *et al.* (2023) in a 16-week study of 113 low-income American adolescents (55.64% girls; mean age 11.29 years) found that physical activity increased by an average of 6.36 minutes per 8 weeks (coefficient = 6.36; $p < 0.001$), with a total increase of approximately 12.72 minutes over 16 weeks. Change in intrinsic motivation was a significant positive predictor of change in daily high-intensity physical activity (coefficient = 2.57; $p = 0.035$), while change in autonomous extrinsic motivation was not a significant predictor ($p = 0.473$). Gender and race/ethnicity had a negligible effect on the rate of change in physical activity during the study (gender $p = 0.067$; race $p = 0.79$), indicating similar rates of improvement in physical activity across all groups.

Thus, adolescents' motivation to engage in regular physical activity is shaped by a complex interaction of internal psychological mechanisms and external contextual factors, where the satisfaction of basic psychological needs for autonomy, competence, and social belonging is a fundamental prerequisite for the development of sustainable motivational patterns. Empirical data demonstrate the qualitative superiority of autonomous forms of motivation over controlled ones in predicting long-term commitment to physical activity, especially when different types of motives are harmoniously integrated and aligned with

individual psychological characteristics, including physical self-concept, body image, and gender-specific motivational profiles. At the same time, the effectiveness of motivational interventions is largely determined by the level of development of adolescents' self-regulatory competencies, in particular, their ability to adaptively set goals, plan and self-monitor, which reveal age dynamics and sensitivity to the social context, which needs to be taken into account when developing differentiated physical education programmes for different age groups of adolescents.

Socio-cultural and environmental factors influencing the motivational sphere of adolescents

L. Liu *et al.* (2025) in a study of 1,286 schoolchildren from different regions of China found parental expectations to be a significant positive predictor of adolescent sports activity ($\beta = 0.208$; $t = 7.634$; $p < 0.001$). The effects of parental expectations differed depending on the components of physical activity: the strongest influence was on the frequency of training ($\beta = 0.238$; $p < 0.001$), slightly weaker on intensity ($\beta = 0.202$; $p < 0.001$) and the smallest on the duration of training ($\beta = 0.184$; $p < 0.001$). Parental expectations explained about 5.7% of the variance in adolescents' sports activity ($R^2 = 0.057$), exerting their influence on motivation indirectly through the satisfaction of basic psychological needs. The sequential mediating effect of parental expectations regarding physical activity through the satisfaction of basic needs and motivation to exercise was 0.052, representing 24.88% of the total effect. According to Y. Jiang & Y. Xiao (2024), based on a sample of 500 adolescents and their parents, family influence on children's physical activity had a direct positive effect on regular physical exercise ($\beta = 0.148$; effect size = 32.81%). The satisfaction of basic psychological needs mediated 25.05% of this influence ($\beta = 0.113$), while the satisfaction from performing exercises additionally mediated 20.39% ($\beta = 0.092$). The sequential mediating effect through self-efficacy and enjoyment of exercise was 0.097 (effect size = 21.50%), revealing a multilevel mechanism of the family environment's influence on the duration of physical activity in adolescents. The family environment influenced both the immediate behaviour model and internal psychological mechanisms.

Gender-specific mechanisms of parental influence can be traced in a study by Y. Yaffe & O. Levental (2023) on a sample of 308 adolescents (143 boys, 165 girls). An authoritarian parenting style was associated with higher autonomous motivation in adolescents indirectly through parental physical activity practices ($\beta = 0.26$; $p < 0.05$), including modelling, encouragement and monitoring. The authoritarian parenting style demonstrated a similar, albeit smaller, positive effect on boys' motivation to engage in physical activity ($\beta = 0.18$; $p < 0.05$). The indirect relationship between paternal authoritarian parenting and adolescents' motivation for physical activity through parental practices was significantly stronger for girls ($\beta = 0.31$) than for boys ($\beta = 0.22$). D.J. Phipps *et al.* (2025), based on data from 88 Finnish parent-child pairs, found that parental autonomous motivation was positively associated with parental autonomous support ($\beta = 0.34$; $p < 0.01$), which, in turn, predicted children's perception of autonomous support ($\beta = 0.41$; $p < 0.001$) and children's autonomous motivation ($\beta = 0.28$; $p < 0.01$). The indirect effect of parental autonomous motivation on children's physical activity, mediated by parental autonomous support, children's perception of such support, and children's autonomous motivation, was 0.039 (95% *CI*: 0.018-0.062; $p < 0.001$). Parental autonomous motivation was positively associated with both parental physical activity ($\beta = 0.47$; $p < 0.001$) and joint parental-child physical activity ($\beta = 0.29$; $p < 0.01$), forming a mechanism for the transmission of motivational patterns within the family. Table 2 below summarises the main levels of socialisation influence on adolescent physical activity, demonstrating their agents, nature of action, and factors that can both strengthen and weaken motivation for physical activity.

Table 2. Multilevel system of social factors shaping adolescents' motivation for physical education

Level of influence	Agents of socialisation	Mechanisms of influence	Positive factors	Negative factors	Degree of influence (%)
Micro level (family)	Parents, siblings, relatives	Modelling, reinforcement, family support and expectations	Joint training, emotional and material support, positive family expectations regarding health	Parental indifference, criticism, excessive demands without support	35-42%
Meso level (education)	Physical education teachers, coaches, specialists	Teaching motor skills, motivation, informational support of competence	Professionalism of the teacher, enthusiasm, a supportive class atmosphere	Formalism, coercion, poor-quality conditions, insufficient number of sessions	22-28%
Meso level (peers)	Friends, team members, classmates, social networks	Group pressure, social identification, imitation, emotional support	Friendly environment, positive competition, sense of belonging	Bullying, social exclusion, negative group dynamics	18-24%
Macro level (media and promotion)	Bloggers, media personalities, advertising campaigns, social media	Information provision, promotion, formation of norms and standards, demonstration of role models	Positive role models, promotion of a healthy lifestyle, viral motivation	Unrealistic standards of beauty, cult of appearance, pressure towards perfection	9-16%
Macro level (public policy)	Government bodies, sports policy, local authorities	Creation of a regulatory environment, ensuring accessibility, regulation of conditions	Accessible gyms and swimming pools, infrastructure development, national programmes	Underfunding, weak infrastructure, formalism in programmes	5-12%

Table 2, Continued

Level of influence	Agents of socialisation	Mechanisms of influence	Positive factors	Negative factors	Degree of influence (%)
Mega level (culture and values)	Society, cultural norms, traditions, mass media	Formation of values and norms, construction of desired behaviours	Cult of health, traditions of physical culture, support of sport as part of identity	Cult of consumption, sedentary lifestyle, low social value of physical activity	2-6%

Source: developed by the authors based on research by L. Liu *et al.* (2025), Z. Li *et al.* (2025), S. Ge *et al.* (2025)

The hierarchy of social influence shown in Table 2, where the family environment demonstrated an almost threefold predominance over state policy and cultural norms, reflected the decisive role of parents as primary agents of socialisation in shaping motivational attitudes in the early stages of development. Positive and negative factors at each level functioned asymmetrically: parental criticism and lack of support influenced the overall picture of motivation, while the professionalism of the coach modified the motivational profile in the direction of competence development. The indirect systemic influence of macro levels (state, media, culture) worked through the transformation of microsystems: state policy on the accessibility of sports facilities influenced the physical activity of adolescents mainly through the expansion of opportunities for family activities and interactions with peers, rather than as an autonomous factor. The research results indicated that strategies to increase motivation for physical activity involved strengthening family and peer support as fundamental structures, while state and media interventions were effective in combination with improvements in the microsocial context.

Current pedagogical approaches have shown differentiated effects on the motivation of different groups of adolescents. H. Zha *et al.* (2025) found in a study of 929 primary school students in southwestern China that cognitive activation teaching strategies (CATS) had a positive effect on physical activity ($\beta = 0.133$; $p < 0.001$) and health-related behaviour ($\beta = 0.087$; $p < 0.001$). Classroom engagement mediated this relationship, with a coefficient from cognitive activation to engagement of $\beta = 0.270$ ($p < 0.001$). Self-efficacy showed the strongest mediating effect, predicting both health-promoting behaviour ($\beta = 0.209$; $p < 0.001$) and physical activity ($\beta = 0.310$; $p < 0.001$). Cognitive activation predicted motivation ($\beta = 0.287$; $p < 0.001$) but did not significantly affect emotional regulation ($\beta = 0.039$; $p = 0.183$). Qualitative data revealed that teachers who used cognitive activation, goal setting, progressive challenges, and constructive feedback contributed to the creation of "productive conflict" in learning. Traditional teaching methods had negative consequences for the formation of positive motivation. A. Hoyo-Guillot *et al.* (2025) conducted an experimental study of 127 students who were divided into groups where sports education models (SEM; $n = 63$) and traditional methods (TM; $n = 64$), found that traditional methods were associated with a deterioration in prosocial values, in particular, positive assessment of others ($p = 0.037$; Cohen's $d = 0.311$). In addition, the TM group showed a significant decrease in the perception of the usefulness of physical education ($p = 0.016$; Cohen's $d = 0.455$), indicating demotivation associated with authoritarian teaching methods. In contrast, the SEM group showed an increase in three prosocial dimensions: giving ($p = 0.015$; Cohen's $d = 0.474$), verbal comforting ($p = 0.019$; Cohen's $d = 0.333$) and solidarity ($p = 0.039$; Cohen's $d = 0.328$).

Innovative educational practices based on self-determination theory have successfully increased adolescents' interest. H. Paap *et al.* (2025) developed and described a longitudinal study that combined face-to-face and web-based support for the needs of autonomy, competence, and relatedness in physical education teachers. The study involved selecting 78 pupils in the first phase and 116 pupils in the second phase, with accelerometer measurements taken at baseline, after one month and after three months. It was expected that students in the experimental group would demonstrate significantly higher intrinsic motivation for physical activity and greater physical activity, as measured by accelerometers, compared to the control group. Teachers were provided with detailed materials on 9 specific behaviours related to supporting needs and 13 behaviours related to common threats to needs, developed based on the taxonomy of A. Ahmadi *et al.* (2023) and adapted to the context of physical education. Teachers completed weekly reports on providing support for realisation needs and avoiding common behaviours, demonstrating a systematic approach to transforming pedagogical practice.

Peer support is a powerful social factor in motivating adolescents to engage in regular physical activity, exerting its influence through multiple psychological mechanisms. Y. Zou *et al.* (2023) in a study of 2,087 adolescents in Shanghai found a direct positive effect of peer support on adherence to physical exercise ($\beta = 0.135$; $p < 0.001$; effect size 59%), mediated through self-efficacy and self-regulation. Peer support predicted self-efficacy with a coefficient of $\beta = 0.493$ ($p < 0.001$), which accounted for 42% of the indirect effect on adherence to physical exercise. The pedagogical model, peer encouragement, and joint participation in physical activity were the most significant components of support. Correlation analysis demonstrated a significant positive relationship between peer support and physical exercise ($r = 0.324$; $p < 0.01$), with a stronger effect in younger adolescent boys than in girls. Digital technologies have transformed traditional mechanisms of social influence, creating new forms of group interaction around physical activity. M. Zhang & X. Li (2024) found in a study of 1,312 Chinese adolescents that the use of the WeRun app was associated with healthy lifestyle behaviours indirectly through social support and social comparison, with no direct effect ($\beta = 0.018$; $p = 0.455$). Social support mediated 43.1% of the relationship between app use and healthy lifestyle behaviour ($B = 0.431$; $t = 7.183$; $p < 0.001$), while social comparison mediated 29.9% of this relationship ($B = 0.299$; $t = 6.102$; $p < 0.001$). The use of gamified elements, including leaderboards and likes, stimulated both competitive motivation and social support among users. WeRun had a positive effect on social support ($\beta = 0.262$; $t = 9.807$; $p < 0.001$)

and social comparison (β = 0.300; $t = 11.426$; $p < 0.001$), demonstrating the role of online communities in shaping motivation for physical activity.

Fitness influencers on social media function as a specific form of social modelling of behaviour that exhibits gender-differentiated effects. J. Durau *et al.* (2022) in two consecutive studies ($N1 = 507$; $N2 = 445$) found that the perceived motivational power of fitness bloggers was a stronger predictor of intention to exercise than attitude towards the blogger in both genders (women γ = 0.541, $p < 0.01$; men γ = 0.518, $p < 0.01$). Women who had a negative body perception showed an increase in their intention to exercise after watching the blogger's video (γ = -0.180; $p < 0.05$), but this effect was not found in men (γ = -0.068, n.s.). The blogger's reliability, knowledge, and attractiveness had a positive effect on perceived motivational force, with reliability being the strongest predictor for women (γ = 0.379, $p < 0.01$) and knowledge for men (γ = 0.413, $p < 0.01$). Engagement in training with YouTube fitness videos positively predicted the intention to exercise for both genders (women γ = 0.431, $p < 0.01$; men γ = 0.426, $p < 0.01$). Peer pressure and social norms modify adolescents' motivational profiles, creating differentiated patterns of engagement in physical activity. Y. Zhao *et al.* (2025) in a study of 571 Chinese adolescents aged around 12 years found that latent profile analysis revealed three motivation profiles: low motivation with high amotivation (8.45%), moderate motivation with high amotivation (60.61%), and high autonomous motivation (30.94%). The third profile showed significantly higher physical activity ($M = 0.176$; $SD = 0.893$) compared to the first profile ($M = -0.309$; $SD = 0.707$; $p < 0.001$) and the second profile ($M = -0.153$; $SD = 0.747$; $p < 0.001$). External regulation (which may reflect peer pressure and social norms) was positively correlated with physical activity ($r = 0.133$; $p < 0.001$), although this effect was weaker compared to internal motivation (r ranged from 0.152 to 0.172, all $p < 0.001$). Boys demonstrated significantly higher physical activity compared to girls ($F(3,364) = 4.714$; $p = 0.030$), indicating gender differences in sensitivity to group influences.

Thus, the formation of adolescents' motivation for systematic physical education takes place in a multi-level system of social influences, where the family environment functions as the main agent of primary socialisation through the mechanisms of parental expectations, behaviour modelling and autonomous support, mediating its influence through the satisfaction of basic psychological needs and the formation of self-efficacy. The pedagogical influence of physical education teachers is implemented differentially depending on the chosen methodological approaches: transformational teaching style and cognitive activation strategies enhance intrinsic motivation by creating a task-oriented climate and supporting competence, while traditional authoritarian methods provoke demotivation and a deterioration of prosocial values. Peer support and digital forms of social interaction create additional channels of motivational influence through mechanisms of social comparison, group identification and behaviour modelling, with their effectiveness showing gender and age specificity, while macro-level factors (government policy, media, cultural norms) exert their influence mainly indirectly through the transformation of micro-social contexts, indicating the need for integrated multi-level interventions to increase adolescents' motivation for physical activity.

Pedagogical technologies and methodological tools for stimulating adolescent motivation for physical culture and sports activities

M. Wang *et al.* (2025) in a meta-analysis of 16 randomised controlled trials with a total sample of 7,472 children and adolescents found that gamified interventions significantly increased moderate-intensity physical activity compared to control (standardised mean difference [*SMD*] 0.15; 95% *CI* 0.01-0.29; $p = 0.04$) and reduced body mass index (*SMD* 0.11; 95% *CI* 0.05-0.18; $p < 0.001$). However, gamified interventions did not have a statistically significant effect on sedentary behaviour (*SMD* 0.07; 95% *CI* -0.07-0.22; $p = 0.33$), daily locations (*SMD* 0.22; 95% *CI* -0.51-0.94; $p = 0.55$) or light physical activity (*SMD* -0.00; 95% *CI* -0.49-0.48; $p = 0.99$). Subgroup analyses revealed that self-determination theory-based interventions demonstrated a stronger effect on moderate-intensity activity (*SMD* 0.39; 95% *CI* 0.01-0.77; $p = 0.04$) compared to other theoretical paradigms. Studies lasting more than 12 weeks had a greater effect compared to shorter programmes. Virtual reality functioned as a promising technology for expanding access to physical activity and increasing motivation. Đ. Hajder *et al.* (2025) found in a systematic review and meta-analysis of 23 studies that virtual reality training significantly improved flexibility, motivation, and cognitive abilities, especially in populations with limited access to traditional exercise methods. The most pronounced effects were observed in programmes lasting 8-12 weeks with moderate to high intensity. Statistical analysis showed highly significant improvements in physical fitness ($M \pm SD = 74.3 \pm 8.2$; $p = 0.0029$), cognitive aspects ($M \pm SD = 82.1 \pm 6.7$; $p = 0.0022$) and health aspects ($M \pm SD = 77.5 \pm 7.9$; $p = 0.0069$). The effect sizes for virtual reality interventions ranged from 0.38 to 0.75 (Cohen's *d*), indicating moderate to large positive effects. Organising classes individually and in groups revealed differentiated effects depending on the motivational profile of adolescents. D. Novak *et al.* (2025) found in a randomised controlled trial of 976 Croatian students (mean age 19.4 ± 1.1 years) that group training significantly increased total physical activity time by more than 10 metabolic equivalent hours per week compared to individual exercise in the control group. When considering different types of activity, the effect of the intervention was stronger for vigorous activity (an increase of almost 6 MET hours per week) compared to walking (2.5 MET hours per week). Complex modelling of heterogeneity showed significantly greater variability in the experimental group, indicating a heterogeneous effect of physical activity and the possibility of different effects for adolescents with different initial levels of motivation. The use of fitness trackers and mobile applications demonstrated an indirect mechanism of influence on motivation through social comparison and support. W.W. Au *et al.* (2024) found in a meta-analysis of 30 studies that wearing a tracker contributed to an increase in moderate-intensity physical activity in children and adolescents. The effectiveness of wearing a tracker depended on the age of the participants: in adolescents over 13 years of age, the effect was greater through the mediation of self-control and goal setting, while in younger participants,

the effect was greater through peer support and family encouragement. Interventions lasting more than 12 weeks showed more sustainable results, while programmes that integrated wearables with multi-component interventions (including behavioural strategies and professional support) showed stronger and more lasting effects.

Emotional experiences during physical education classes mediate between the type of motivation and behavioural consequences. M.E. Işıkgöz (2025) found in a study of 1,399 Turkish high school students that intrinsic motivation showed the strongest links with positive emotions of achievement, particularly pride ($r = 0.73$; $p < 0.001$) and satisfaction ($r = 0.55$; $p < 0.001$). In the structural equation analysis, intrinsic motivation positively contributed to the emergence of positive emotions of achievement ($\beta = 0.63$; $p < 0.001$) and the disappearance of negative emotions ($\beta = -0.68$; $p < 0.001$). External motivation showed a weak positive correlation with positive emotions ($\beta = 0.07$; $p < 0.001$), while no significant correlation with negative emotions was found ($\beta = -0.02$; $p = 0.130$). The study found that constructive feedback and support for autonomy by physical education teachers were key mechanisms for satisfying the need for competence and autonomy, which led to the formation of intrinsic motivation and positive emotions of achievement. Innovative pedagogical approaches that give students more time for practical activities and independent study of the material show potential for enhancing autonomous motivation. P.K. Yip *et al.* (2023) found in a randomised controlled study of 111 young people that a "flipped learning" approach, in which students watched videos before class and had more time for practice in class, led to significantly higher autonomous motivation and moderately intense physical activity. In the experimental group, where the "flipped learning" approach was used, autonomous motivation before the third lesson was $M = 3.28$ ($SD = 0.66$) compared to the control group ($M = 3.24$; $SD = 0.61$). In the third lesson, the positive correlation between moderate-intensity physical activity and autonomous motivation was $r = 0.266$ ($n = 57$; $p < 0.05$) only in the experimental group. With an intervention duration of more than 12 weeks, the results remained stable, indicating that systematic feedback and activity choice increased long-term motivation.

Empirical studies reveal the nuances of the perception of autonomy and its impact on the long-term engagement of adolescents in physical activity. A. Beddoe *et al.* (2025) found in a qualitative study of 13 British male adolescents aged 13-17 that perceived autonomy was associated with motivation to participate in physical activity. Boys who received autonomous support from parents and coaches, including choice of activity and flexibility in goal setting, reported higher intrinsic motivation. In particular, respondents noted the availability of certain types of activities (e.g., running) that did not require special equipment or space as important factors in maintaining motivation. In contrast, boys who were constrained by rigid expectations either stopped physical activity or sought alternative activities. Participants reported discontinuing team sports due to feelings of coercion, excessive training duration, and loss of energy during activities that did not match their interests. The study found that praise for effort and constructive criticism, rather than praise for ability, were associated with increased intrinsic motivation and long-term engagement. The competitive context of physical activity modifies motivational patterns depending on the balance between competitive and cooperative elements. M. del Mar García-Galán *et al.* (2025) found in a study of 240 Spanish students that a competitive approach to physical activity correlated with stronger commitment to both competitiveness and cooperativeness, but with a more noticeable concentration on higher levels of cooperativeness. Group activities such as sports and board games showed a stronger positive effect on cooperativeness (regression coefficients $\beta = 0.195$ and $\beta = 0.255$, respectively; $p < 0.0001$), while video games, which are more competitive in nature, had no statistically significant relationship with cooperativeness ($\beta = 0.066$; $p = 0.08$). A blurred approach in team sports activated both motivational systems with a higher level of team interaction and mutual support than in individual sports. The study found that properly formulated feedback with an emphasis on effort and group achievements strengthened achievement motivation in group activities.

The problem of getting teenagers involved in regular sports and physical education remains relevant in the context of high dropout rates, especially among girls. Y. Zhang *et al.* (2024) found in a systematic review of 11 studies that the main reasons for adolescents discontinuing sports activities included both psychological and structural factors. At the psychological level, perceptions of ability to succeed functioned as productive factors, while their absence predicted a higher likelihood of discontinuing participation. The study found that gender differences in discontinuing sports were significant, with higher rates among girls than boys. Coach leadership and the quality of the motivational climate determined critical factors: autonomous support, as opposed to a controlling style, was associated with a higher likelihood of continuing to participate in sports. Parental and peer support functioned as a significant protective factor in 60% of studies, demonstrating the consistent influence of the social system on retaining adolescents in sport. Physical activity is particularly important for adolescents with chronic diseases, where motivational barriers are combined with medical restrictions and social stigmatisation. B. Sañudo *et al.* (2024) in a systematic review of 52 controlled studies on a total sample of 2,352 children and adolescents with chronic diseases found that sports activities effectively improved both physical and psychosocial outcomes. The studies covered interventions for autism, cerebral palsy, AIDS (acquired immunodeficiency syndrome), obesity, cancer, and other chronic diseases. The average adherence was about 85%, with studies reporting adherence ranging from 75% to 100%. Psychosocial outcomes showed improvements in behavioural problems, social skills, executive functions, and health-related quality of life. Activities that included group sports and team interaction showed additional benefits in social integration and team building. The study emphasised that programmes lasting 8-12 weeks and occurring 2-3 times per week demonstrated an optimal balance between accessibility and effectiveness.

Long-term adapted physical activity programmes reveal specific strategies for preventing demotivation in vulnerable adolescent groups. N. Stöcker *et al.* (2024) in the KidsTUMove project described a comprehensive physical

activity programme for children and adolescents with chronic diseases, which was developed over 17 years (since 2007) with the participation of more than 2,750 children. Preliminary studies indicated that the WHO (World Health Organisation) recommendations for 60 minutes of daily physical activity and improved quality of life were achieved. The programme provided multidisciplinary supervision, including preliminary medical examinations, medical care and direct supervision during classes. Strategies to prevent demotivation included personalised support in small groups, parental involvement, establishing social contacts with peers with similar problems, and providing a variety of activities without pressure to perform. The study showed that participation in camps and regular groups was associated with a sustained improvement in self-esteem, reduced isolation, and the development of a sense of belonging to the community. Organised sports participation functions as a tool for social integration for adolescents from disadvantaged socio-economic backgrounds. T. Filges *et al*. (2024) conducted a systematic review of 13 studies of organised sports activities for low-income and at-risk youth and found that participation in sports activities had a positive impact on psychosocial functioning. The standardised mean difference for overall psychosocial adjustment at post-intervention was 0.70 (95% *CI* 0.28-1.11), with low heterogeneity. For depressive symptoms at 0-3 years follow-up, the standardised mean difference was 0.02 (95% *CI* -0.01-0.06), indicating a weak effect. The median number of participants in the studies was 316, ranging from 95 to 222. Interventions lasted from one week to 23 years, but most focused on short-term effects. The study emphasised that organised sports participation served as a resource for levelling risky and problematic behaviour in adolescents with unfavourable background circumstances. In addition, sports programmes with an emphasis on teamwork, social skills and positive responsibility showed greater effects on reducing problem behaviour and improving emotional functioning.

Thus, current pedagogical technologies for stimulating adolescents' motivation to engage in physical education and sports activities demonstrate the highest effectiveness when digital tools (gamification, virtual reality, fitness trackers) with the principles of self-determination theory, especially for programmes lasting more than 12 weeks, which ensures sustainable behavioural changes through mechanisms of self-control, social comparison and autonomy support. The organisational forms of classes have different effects depending on the motivational profile: group training mainly activates both competitive and cooperative motivational systems, enhancing social integration and team interaction, while individualised approaches with a choice of activities and flexible goal setting provide higher intrinsic motivation by satisfying the need for autonomy and competence. A critical factor in engaging adolescents in systematic exercise is the creation of a supportive motivational climate through transformational leadership by coaches, constructive feedback with an emphasis on effort and progress, and the involvement of parents and peers as agents of social support, which is particularly important for vulnerable groups, including adolescents with chronic diseases and adverse socio-economic status, where adapted programmes with personalised support demonstrate high adherence rates (up to 85%) and comprehensive psychosocial effects alongside physical improvements.

Comprehensive recommendations for motivating adolescents to engage in physical activity

The results of the analysis of scientific sources allowed to formulate a set of recommendations aimed at improving the effectiveness of motivating adolescents to engage in physical culture. These recommendations were based on the principles of contemporary psychology of motivation and physical education pedagogy and took into account the age-related features of the psychophysiological development of individuals aged 12-17. The organisation of the physical education teaching process requires the creation of conditions to satisfy the need for autonomy by providing the opportunity to choose the type of physical activity, the pace of exercise and the level of difficulty of the tasks. The implementation of the principle of variability involves the development of modular programmes in which the basic component is combined with elective areas. The need for competence is met through a system of graded tasks using physical fitness testing and a differentiated approach to the organisation of the educational process. S. Pavlović *et al.* (2025) found that among boys, the highest activity during physical education classes was associated with a higher perception of sports competence ($M = 3.86$, $SD = 0.47$ in the most active group compared to $M = 2.19$, $SD = 0.88$ in the least active group; $p < 0.001$), which indicates the importance of creating conditions for a sense of effectiveness in one's own activities. Working at an appropriate level of difficulty contributes to the accumulation of positive experiences of success and an increase in self-perceived competence. Feedback from the teacher should focus on the efforts made, the strategies used, and the progress made in relation to the student's previous results. A. Beddoe *et al.* (2025) showed that praise for effort and constructive criticism were associated with increased intrinsic motivation and long-term engagement, while praise for ability could lead to avoidance of challenges. Peer teaching, where more experienced students help less prepared ones, simultaneously satisfies the needs for competence and belonging of both parties involved.

The use of fitness trackers allows teenagers to monitor their own progress in objective terms, which increases their awareness of the effectiveness of training. Gamification of the learning process through the introduction of a system of points and achievement levels appeals to the interest in game mechanics inherent in adolescence, but should be accompanied by a gradual transition from external to internal motivators. Educational programmes for parents should focus on making them aware of the role of their own behaviour as a model for their children. Family physical activity creates a norm of healthy living and associates physical activity with positive emotions. Parental support should take the form of an autonomous style that recognises the adolescent's right to their own sporting preferences and emotional support. A controlling style has been associated with increased anxiety and a greater likelihood of giving up sport.

At the organisational level of educational institutions, it is necessary to rethink the content of physical education lessons by integrating various types of physical activity,

including the latest fitness trends, functional training, dance programmes and non-traditional sports. Expanding the range of activities on offer increases the likelihood that every teenager will find an activity that suits their interests. Material and technical support, including the latest equipment and sanitary and hygienic conditions, directly affects student motivation. The formation of a positive attitude requires the integration of an educational component aimed at developing physical literacy. Teenagers should learn about the physiological mechanisms of the impact of physical activity on the body, training principles and self-control methods. Awareness of the link between regular exercise and specific positive changes strengthens internal motivation through the mechanism of cognitive understanding of the value of physical activity.

Prevention of demotivation involves paying attention to at-risk adolescents who have had negative experiences or low self-esteem regarding their physical abilities. Individual adaptation programmes should begin with diagnosing the causes of negative attitudes and gradually building positive experiences through accessible tasks. Creating separate groups for adolescents with special needs provides a psychologically safe environment without social comparison with more developed peers. A gender-sensitive approach takes into account differences in motivational priorities between boys and girls. S. Pavlović *et al.* (2025) found gender differences in the relationship between physical self-concept and physical activity: girls with the highest level of activity had higher ratings of satisfaction with their appearance ($M = 3.94$, $SD = 0.61$ compared to $M = 3.12$, $SD = 0.39$ in the low activity group; $p = 0.01$), while boys showed higher sensitivity to perceptions of athletic competence ($M = 3.86$, $SD = 0.47$ in the most active group compared to $M = 2.19$, $SD = 0.88$ in the least active group; $p = 0.01$). I. Soós *et al.* (2019) found that girls showed higher levels of autonomous motivation in the context of formal physical education, while boys reported more perceived support and freedom of choice in the context of competitive activities. Pedagogical practice should take these gender characteristics into account, focusing on the functional capabilities of the body and the feeling of satisfaction from movement, since K. Sick *et al.* (2025) showed that a negative perception of one's own appearance reduced the likelihood of continuing physical education classes.

Teaching goal-setting skills should be based on the principles of specificity, measurability and achievability. Self-monitoring techniques through journaling or the use of mobile apps allow adolescents to track their progress and adjust their goals. Taking into account age-related characteristics of time discounting involves the use of more frequent forms of encouragement for younger adolescents, while older ones can work with long-term goals. The organisation of group dynamics should balance competitive and cooperative elements depending on the characteristics of the group. Structured team activities, where success depends on mutual assistance, promote the development of cooperation and social cohesion. Preventing dropouts requires systematic monitoring of early signs of demotivation and timely intervention through programme adjustments or additional support.

Working with adolescents with chronic illnesses requires a specialised approach that combines medical supervision with psychological support. Organising classes in small groups of adolescents with similar illnesses reduces feelings of stigmatisation and creates a supportive environment. The involvement of peers as agents of motivational support is implemented through structured mentoring programmes, which simultaneously strengthens the motivation of both parties by satisfying their needs for belonging and competence. At the level of public policy, it is necessary to ensure the systematic training of physical education teachers in the field of motivational theories and relevant pedagogical technologies. Involving parents in school programmes through joint sports activities increases the consistency of motivational influences between the home and school environments. The effectiveness of programmes should be monitored on the basis of objective indicators of activity combined with subjective measures of the quality of motivation and psychological well-being of adolescents.

Conclusions

The conducted study made it possible to systematise psychological, sociocultural and pedagogical factors involved in the formation of adolescents' motivation for physical education on the basis of a comprehensive analysis of 51 international publications from 2011-2025, with a particular emphasis on the period 2019-2025. Analysis of psychological determinants established that intrinsic motivation proved to be the only significant predictor of adolescents' daily physical activity compared with controlled forms of regulation, while satisfaction of the basic psychological needs for autonomy, competence and social relatedness mediated the relationship between a supportive environment and the development of stable motivational patterns. Gender differences in motivational profiles were manifested in that boys demonstrated greater sensitivity to perceived physical competence and competitiveness, whereas girls were more strongly oriented towards aesthetic aspects and social interaction, confirming the need for gender-sensitive pedagogical approaches. Examination of sociocultural factors revealed a hierarchical structure of influences in which the family environment functioned as the most influential agent of primary socialisation through mechanisms of parental expectations and behavioural modelling, with an effect of approximately 25% mediated through satisfaction of basic needs, while peer support and digital forms of social interaction created additional channels of motivational influence through social comparison and group identification. Analysis of pedagogical technologies showed that gamified interventions based on self-determination theory and lasting more than 12 weeks significantly increased moderate-intensity physical activity compared with traditional methods, while group-based training demonstrated a stronger effect on vigorous activity than individual formats, and virtual reality and fitness trackers exhibited an indirect mechanism of influence through self-monitoring and social support.

The results of the study enabled the development of a set of evidence-based recommendations structured across three levels of intervention: the micro level of individual pedagogical interaction, with an emphasis on supporting autonomy through providing choice in types of physical activity and constructive feedback focused on effort rather than ability; the meso level of organising the educational

process through integration of diverse forms of physical activity and involvement of parents as agents of motivational support; and the macro level of systemic policies through ensuring access to sports infrastructure and professional training of teachers in the field of motivational theories. A limitation of the study was the geographical concentration of most of the analysed works in Western Europe, North America and East Asia. Promising directions for further research include the conduct of long-term longitudinal studies in different cultural contexts using objective methods of measuring physical activity through accelerometry to test the stability of motivational changes and to validate the developed recommendations within the Ukrainian educational system, taking into account specific socio-economic challenges.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Ahmadi, A., *et al.* (2023). A classification system for teachers' motivational behaviors recommended in self-determination theory interventions. *Journal of Educational Psychology*, 115(8), 1158-1176. doi: 10.1037/edu0000783.

[2] Ahmedov, F., Shopulatov, A., Muqimov, M., Salikhova, R., Kuldashev, S., & Zakirov, F. (2025). Pre-competition anxiety and fear of failure in athletes of varying age and gender. *Slobozhanskyi Herald of Science and Sport*, 29(2), 114-120. doi: 10.15391/snsv.2025-2.02.

[3] Au, W.W., *et al.* (2024). Effect of wearable activity trackers on physical activity in children and adolescents: A systematic review and meta-analysis. *The Lancet. Digital Health*, 6(9), 625-639. doi: 10.1016/S2589-7500(24)00139-0.

[4] Beddoe, A., Hings, R., & Kerner, C. (2025). "Making choices for yourself": A qualitative visual methods study on adolescent boys' autonomy in physical activity. *Journal of Adolescent Research*. doi: 10.1177/07435584251330810.

[5] Butenko, H. (2025). Physical culture and recreational activity of adolescents in the aspect of motivational priorities. *Actual Problems of Physical Education and Methods of Sports Training*, 3, 25-37. doi: 10.31652/3041-2463/2025-3-2.

[6] Cefai, C., Barrado, B., Gimenez, G., & Cavioni, V. (2025). Adolescents' life satisfaction, physical activity, and the moderating role of gender: A cross-country, multilevel analysis in 64 countries. *Children*, 12(10), article number 1375. doi: 10.3390/children12101375.

[7] Courtney, J.B., Li, K., Nelson, T.L., Nuss, K.J., Haynie, D.L., Iannotti, R.J., & Simons-Morton, B.G. (2021). Autonomous motivation and action planning are longitudinally associated with physical activity during adolescence and early adulthood. *Psychology of Sport and Exercise*, 56, article number 101974. doi: 10.1016/j.psychsport.2021.101974.

[8] de Oliveira Barbosa, R., Castilho Dos Santos, G., da Silva, J.M., de Souza Silva, T.M., Dias, P. H.G., Correa, R.C., Sasaki, J.E., & Stabelini Neto, A. (2024). Does autonomous motivation and self-efficacy mediate associations between environmental factors and physical activity in adolescents? *BMC Psychology*, 12, article number 548. doi: 10.1186/s40359-024-02055-3.

[9] Del Mar García-Galán, M., Nevado-Bulnes, A.M., Merino, J.M., & Román, Á.C. (2025). Competitiveness versus cooperativeness linked to leisure activities in young university students in Spain. *BMC Psychology*, 13, article number0 852. doi: 10.1186/s40359-025-03190-1.

[10] Deng, A., Zarrett, N., Moon, J., & Sweeney, A.M. (2023). Changing trajectory of daily physical activity levels among at-risk adolescents: Influences of motivational mechanisms. *BMC Public Health*, 23, article number 2089. doi: 10.1186/s12889-023-16949-1.

[11] Dishman, R.K., McIver, K.L., Dowda, M., & Pate, R.R. (2018). Declining physical activity and motivation from middle school to high school. *Medicine and Science in Sports and Exercise*, 50(6), 1206-1215. doi: 10.1249/MSS.0000000000001542.

[12] Durau, J., Diehl, S., & Terlutter, R. (2022). Motivate me to exercise with you: The effects of social media fitness influencers on users' intentions to engage in physical activity and the role of user gender. *Digital Health*, 8. doi: 10.1177/20552076221102769.

[13] Filges, T., Verner, M., Ladekjær, E., & Bengtsen, E. (2024). Participation in organised sport to improve and prevent adverse developmental trajectories of at-risk youth: A systematic review. *Campbell Systematic Reviews*, 20(1), article number e1381. doi: 10.1002/cl2.1381.

[14] Frömel, K., Welk, G., Groffik, D., Jakubec, L., Dygrýn, J., & Mitáš, J. (2025). Adolescent physical activity during school days: A comparative study before and after COVID-19 pandemic restrictions. *Frontiers in Public Health*, 13, article number 1488153. doi: 10.3389/fpubh.2025.1488153.

[15] Ge, S., Zhao, Y., Song, H., Guo, X., & Song, C. (2025). A multilevel impact study of Chinese adolescents' sports participation based on ecological models of health behavior: A structural equation model analysis. *Frontiers in Psychology*, 16, article number 1593491. doi: 10.3389/fpsyg.2025.1593491.

[16] Goddard, S.G., Reece, L.J., Vella, S.A., & Swann, C. (2025). Goal setting in youth sport: Are we unintentionally contributing to dropout? *British Journal of Sports Medicine*, 59(19), 1325-1327. doi: 10.1136/bjsports-2025-110061.

[17] Hajder, Đ., *et al.* (2025). A systematic review and meta-analysis of virtual and traditional physical activity programs: Effects on physical, health, and cognitive outcomes. *Healthcare*, 13(7), article number 711. doi: 10.3390/healthcare13070711.

[18] Harbichová, I., Rusnáková, K., Scheier, L.M., & Komarc, M. (2025). Latent profiles of sport motivation in Czech university students: An exploratory person-centered approach using the sport motivation scale. *European Journal of Sport Science*, 25(5), article number e12286. doi: 10.1002/ejsc.12286.
[19] Hoyo-Guillot, A., Fernández, F.T.G., & Ruíz-Montero, P.J. (2025). Effects of sport education model and physical fitness on motivation and prosociality for a healthy approach in secondary students using an experimental design. *Sports*, 13(8), article number 274. doi: 10.3390/sports13080274.
[20] Hryshchenko, S.V., Kurtova, H.Yu., Bashtovenko, O.A., Tolchieva, H.V., & Kvak, O.V. (2024). Physical activity as a component of a healthy lifestyle of Ukrainian adolescents aged 11-14. *Modern Pediatrics. Ukraine*, 6(142), 104-112. doi: 10.15574/SP.2024.6(142).104112.
[21] Hu, Q., Li, P., Jiang, B., & Liu, B. (2023). Impact of a controlling coaching style on athletes' fear of failure: Chain mediating effects of basic psychological needs and sport commitment. *Frontiers in Psychology*, 14, article number 1106916. doi: 10.3389/fpsyg.2023.1106916.
[22] Işıkgöz, M.E. (2025). Intrinsic vs. extrinsic motivation in high school physical education: Which fuels adolescent achievement emotions better? *PloS One*, 20(6), article number e0327393. doi: 10.1371/journal.pone.0327393.
[23] Jiang, Y., & Xiao, Y. (2024). The association between family physical activity environment and exercise adherence in adolescents: A chain mediation model. *Scientific Reports*, 14, article number 22117. doi: 10.1038/s41598-024-72964-1.
[24] Kalajas-Tilga, H., Koka, A., Hein, V., Tilga, H., & Raudsepp, L. (2020). Motivational processes in physical education and objectively measured physical activity among adolescents. *Journal of Sport and Health Science*, 9(5), 462-471. doi: 10.1016/j.jshs.2019.06.001.
[25] Li, Z., Xie, S., & Chen, W. (2025). The influence of environment on adolescents' physical exercise behavior based on family community and school micro-systems. *Scientific Reports*, 15, article number 12024. doi: 10.1038/s41598-025-91387-0.
[26] Litt, D.M., Iannotti, R.J., & Wang, J. (2011). Motivations for adolescent physical activity. *Journal of Physical Activity & Health*, 8(2), 220-226. doi: 10.1123/jpah.8.2.220.
[27] Liu, L., Li, T., Long, J., Jin, H., & Ahn, J.W. (2025). The influence of parental expectations on adolescents' physical activity: A chain mediation model of basic psychological needs and exercise motivation. *Frontiers in Psychology*, 16, article number 1662714. doi: 10.3389/fpsyg.2025.1662714.
[28] Malchrowicz-Mośko, E., Castañeda-Babarro, A., & Guereño, P.L. (2020). On the way to the marathon-motivation for participating in mass running events among children and adolescents: Results of the Poznan half marathon pilot study. *International Journal of Environmental Research and Public Health*, 17(14), article number 5098. doi: 10.3390/ijerph17145098.
[29] Martins, J., Costa, J., Sarmento, H., Marques, A., Farias, C., Onofre, M., & Valeiro, M.G. (2021). Adolescents' perspectives on the barriers and facilitators of physical activity: An updated systematic review of qualitative studies. *International Journal of Environmental Research and Public Health*, 18(9), article number 4954. doi: 10.3390/ijerph18094954.
[30] Novak, D., Čule, M., Kim, J., Kim, R., & Subramanian, S.V. (2025). Individual versus group exercise effect on youth physical activity levels: A randomised controlled trial. *BMJ Open Sport & Exercise Medicine*, 11(1), article number e002024. doi: 10.1136/bmjsem-2024-002024.
[31] Paap, H., Koka, A., & Tilga, H. (2025). A longitudinal evaluation of an intervention program for physical education teachers to promote adolescent motivation and physical activity in leisure time: A study protocol. *Methods and Protocols*, 8(2), article number 34. doi: 10.3390/mps8020034.
[32] Pavlović, S., Pelemiš, V., Badrić, M., Stević, D., & Mitrović, N. (2025). Moving minds: How physical activity shapes motivation and self-concept in school children. *Behavioral Sciences*, 15(5), article number 629. doi: 10.3390/bs15050629.
[33] Phillips, C.B., Hurley, J.C., Angadi, S.S., Todd, M., Berardi, V., Hovell, M.F., & Adams, M.A. (2020). Delay discount rate moderates a physical activity intervention testing immediate rewards. *Behavioral Medicine*, 46(2), 142-152. doi: 10.1080/08964289.2019.1570071.
[34] Phipps, D.J., Green, W.T., Lintunen, T., Knittle, K., & Hagger, M.S. (2025). Linking autonomy-supportive parenting with their children's autonomous motivation toward, and participation in physical activity. *International Journal of Behavioral Medicine*, 32, 969-975. doi: 10.1007/s12529-025-10358-x.
[35] Rak, L.I., Kashina-Yarmak, V.L., & Yeshchenko, A.V. (2024). Physical activity of adolescents in wartime conditions, ways to optimize it. *Modern Pediatrics. Ukraine*, 7(143), 53-61. doi: 10.15574/SP.2024.7(143).5361.
[36] Ryan, R.M., & Deci, E.L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* New York: The Guilford Press. doi: 10.1521/978.14625/28806.
[37] Sañudo, B., Sánchez-Oliver, A.J., Fernández-Gavira, J., Gaser, D., Stöcker, N., Peralta, M., Marques, A., Papakonstantinou, S., Nicolini, C., & Sitzberger, C. (2024). Physical and psychosocial benefits of sports participation among children and adolescents with chronic diseases: A systematic review. *Sports Medicine – Open*, 10, article number 54. doi: 10.1186/s40798-024-00722-8.
[38] Schmid, M.J., Charbonnet, B., Conzelmann, A., & Zuber, C. (2021). More success with the optimal motivational pattern? A prospective longitudinal study of young athletes in individual sports. *Frontiers in Psychology*, 11, article number 606272. doi: 10.3389/fpsyg.2020.606272.

[39] Sick, K., Pila, E., Gilchrist, J.D., Gohari, M.R., Patte, K.A., & Leatherdale, S. (2025). Prospective relations between self-concept and adolescent physical education participation: A sex stratified analysis. *Journal of Adolescence*, 97(4), 1034-1046. doi: 10.1002/jad.12476.
[40] Soos, I., Dizmatsek, I., Ling, J., Ojelabi, A., Simonek, J., Boros-Balint, I., Szabo, P., Szabo, A., & Hamar, P. (2019). Perceived autonomy support and motivation in young people: A comparative investigation of physical education and leisure-time in four countries. *Europe's Journal of Psychology*, 15(3), 509-530. doi: 10.5964/ejop.v15i3.1735.
[41] Stöcker, N., Gaser, D., Oberhoffer-Fritz, R., & Sitzberger, C. (2024). KidsTUMove – a holistic program for children with chronic diseases, increasing physical activity and mental health. *Journal of Clinical Medicine*, 13(13), article number 3791. doi: 10.3390/jcm13133791.
[42] van de Groep, S., Sweijen, S.W., de Water, E., & Crone, E.A. (2023). Temporal discounting for self and friends in adolescence: A fMRI study. *Developmental Cognitive Neuroscience*, 60, article number 101204. doi: 10.1016/j.dcn.2023.101204.
[43] Wang, M., Xu, J., Zhou, X., Li, X., & Zheng, Y. (2025). Effectiveness of gamification interventions to improve physical activity and sedentary behavior in children and adolescents: Systematic review and meta-analysis. *JMIR Serious Games*, 13, article number e68151. https://doi.org/10.2196/68151.
[44] Yaffe, Y., & Levental, O. (2023). Paternal and maternal parenting style and adolescents' physical activity motivation: Indirect effects through parental physical activity related practices. *Current Psychology*, 43, 7297-7307. doi: 10.1007/s12144-023-04931-4.
[45] Yip, P.K., Cheng, L., & Cheung, P. (2023). The association of children's motivation and physical activity levels with flipped learning during physical education lessons. *European Physical Education Review*, 29(4), 601-618. doi: 10.1177/1356336X231170990.
[46] Ylitalo, K.R., Smith, J., Cox, W., Lucas, R., Niceler, B., & Umstattd Meyer, M.R. (2023). The role of self-regulation strategies in physical activity behavior change: results from an exercise prescription program at a Federally Qualified Health Center. *Psychology, Health & Medicine*, 28(10), 2798-2812. doi: 10.1080/13548506.2022.2143540.
[47] Zha, H., Ding, X., & Li, W. (2025). Innovative approaches in physical education: Leveraging cognitive activation to boost student outcomes. *Frontiers in Psychology*, 16, article number 1481381. doi: 10.3389/fpsyg.2025.1481381.
[48] Zhang, M., & Li, X. (2024). Maintaining healthy lifestyle through fitness app use: A parallel mediation model from a nationwide survey. *Digital Health*, 10. doi: 10.1177/20552076241277483.
[49] Zhang, Y., Wang, F., Szakál, Z., Bíró, Z., Kovács, M., Őrsi, B., & Kovács, K.E. (2024). Why do students drop out of regular sport in late adolescent? The experience of a systematic review. *Frontiers in Public Health*, 12, article number 1416558. doi: 10.3389/fpubh.2024.1416558.
[50] Zhao, Y., Wu, Q., & Zheng, W. (2025). Motivation and physical activity across Chinese adolescents: Based on latent profile analysis. *PloS One*, 20(7), article number e0328383. doi: 10.1371/journal.pone.0328383.
[51] Zou, Y., Liu, S., Guo, S., Zhao, Q., & Cai, Y. (2023). Peer support and exercise adherence in adolescents: The chain-mediated effects of self-efficacy and self-regulation. *Children*, 10(2), article number 401. doi: 10.3390/children10020401.

Формування мотивації до занять фізичною культурою у підлітковому віці

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Анотація. Зниження фізичної активності підлітків в умовах цифровізації та зростаючої навчальної зайнятості актуалізує необхідність розуміння механізмів формування стійкої мотивації до систематичних занять фізичною культурою у віковому періоді 11-18 років. Метою роботи стало виявлення та узагальнення психологічних детермінант, соціокультурних впливів та педагогічних засобів, які сприяють розвитку мотивації підлітків до фізкультурно-спортивної діяльності з урахуванням сучасних цифрових інструментів. Дослідження реалізовано через систематичний аналіз 43 рецензованих публікацій за період 2015-2025 років з міжнародних баз даних із застосуванням контент-аналізу, тематичної систематизації та порівняльного зіставлення ефективності різних педагогічних технологій. Аналіз психологічних чинників встановив, що внутрішня мотивація була ключовим предиктором щоденної фізичної активності підлітків, при цьому задоволення базових психологічних потреб опосередковувало приблизно 25 % впливу батьківської підтримки на рівень активності. Гендерні відмінності проявилися у тому, що хлопці демонстрували вищу орієнтацію на сприйняття фізичної компетентності та змагальність, тоді як дівчата більшою мірою цінували естетичні аспекти та соціальну взаємодію. Дослідження соціокультурних факторів виявило ієрархічну структуру впливів, де родинне середовище відігравало роль первинного агента соціалізації через механізми батьківських очікувань та моделювання поведінки, а підтримка однолітків та цифрові форми взаємодії створювали додаткові канали мотиваційного впливу. Аналіз педагогічних технологій продемонстрував, що гейміфіковані втручання на основі теорії самодетермінації тривалістю понад 12 тижнів збільшували помірно-інтенсивну фізичну активність, при цьому групові тренування виявляли сильніший ефект порівняно з індивідуальними формами. Результати дозволили розробити трирівневу систему рекомендацій для педагогів, тренерів та організаторів фізкультурно-спортивної роботи, що охоплює індивідуальну педагогічну взаємодію, організацію освітнього процесу та системні політики з акцентом на підтримку автономії, компетентності та соціальної приналежності підлітків. Практичне значення полягає у створенні доказової бази для розробки ефективних програм підвищення фізичної активності молоді з урахуванням вікових, гендерних та культурних особливостей

Ключові слова: базові психологічні потреби; самодетермінація; цілепокладання; гейміфікація; автономія; цифрові інструменти

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 30.09.2025.Revised: 31.03.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.853.25:796.015.13
DOI: 10.69587/tppcs/1.2026.24

Comparative analysis of technical and tactical training in traditional (Japanese) and Brazilian jiu-jitsu

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Abstract. The study aimed to identify the specific characteristics of the technical and tactical training of athletes in traditional and Brazilian jiu-jitsu. The research methodology was based on the use of structural analysis, comparison and theoretical modelling. The study revealed differences in the structure of the technical repertoire of the two styles, manifested in the priority given to throwing techniques, linearity and regulated movements in traditional jiu-jitsu, and a focus on positional control, variability and adaptability in Brazilian jiu-jitsu. The study revealed that in traditional (Japanese) jiu-jitsu, the standing position dominates as the primary phase for executing technical actions, whereas in Brazilian jiu-jitsu, the ground position is central. Differences in the development of tactical skills have been identified, manifesting in the linearity of tactical schemes and a focus on achieving results quickly in the traditional style, and in the gradual acquisition of positional advantage, flexibility and adaptability of decisions in Brazilian jiu-jitsu. The interconnection between technique and tactics has been substantiated; in traditional jiu-jitsu, this interconnection is more rigidly regulated, whereas in Brazilian jiu-jitsu, it is dynamic and variable. An integrated model of technical and tactical training has been developed, combining basic technical, positional control, tactical variation and competitive integration components, and providing for continuous transitions between the phases of a bout. An example of a training session is presented, demonstrating the practical application of the model through the step-by-step development of skills and their integration into competitive activity. The study found that the use of varied sparring and situational exercises contributes to the development of adaptive thinking and the effectiveness of athletes' technical and tactical actions. The results of the study confirmed the advisability of integrating the structured nature of traditional approaches with the variability of practices to enhance the effectiveness of athletes' technical and tactical training. The practical significance of the study lies in the possibility of using the developed integrated model and the proposed training approaches to improve the effectiveness of the training process for athletes

Keywords: training methods; training process; relationship between technique and tactics; technical repertoire; positional control

Introduction

As sports training evolves, there is a growing need to consider the specific characteristics of different schools of jiu-jitsu. Japanese (traditional) and Brazilian jiu-jitsu have developed distinct technical repertoires, tactical approaches to combat, and training methodologies, all of which influence the structure of athletes' physical and technical

Suggested Citation: Hryshko, L., Kravchenko, K., & Vilianskyi, V. (2026). Comparative analysis of technical and tactical training in traditional (Japanese) and Brazilian jiu-jitsu. *Theory and Practice of Physical Culture and Sports*, 5(1), 24-35. doi: 10.69587/tppcs/1.2026.24.

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readiness. The variety of approaches to executing techniques, priorities in standing and ground positions, as well as different principles of training design, necessitate a systematic comparison of these approaches. Considering these features helps to improve the soundness of the choice of training methods in sporting practice. Discrepancies in the technical and tactical approaches of traditional and Brazilian jiu-jitsu complicate the definition of universal criteria for assessing athletes' fitness. The mismatch between the structure of technical actions and tactical models of match conduct requires the harmonisation of approaches to their analysis and interpretation in the training process.

C.G. Almeda *et al.* (2023) investigated the relationship between training experience, training preferences and fighting style among jiu-jitsu athletes. Body composition, strength and power were analysed in relation to individual training characteristics. The results revealed differentiated relationships between fighting style and physical qualities. Variability in technical and tactical approaches was also found depending on the athletes' experience. A. Artyushenko *et al.* (2025) found that for 14-15-year-old boys in mixed martial arts, a method combining general physical training with specialised technical and tactical exercises is effective. They emphasised the importance of gradually increasing the intensity of training and incorporating the age-related characteristics of the body.

V. Mocherniuk & V. Leitsyus (2025) found that, during the initial basic training phase, systematic instruction in basic technical and tactical movements and jiu-jitsu is central. They justified the use of a step-by-step approach, progressing from simple movements to complex combinations in simulated combat conditions. B. Hanley (2023) demonstrated that jiu-jitsu training contributes to the development of athletes' mental resilience, particularly self-control, emotional regulation and the ability to cope with stressful situations. The author emphasises the role of the training process and competitive activity as factors in the development of psychological endurance. C. Jones *et al.* (2026) examined the characteristics of coaching in jiu-jitsu within the context of ecological dynamics. The principles of structuring the training process and making tactical decisions were analysed. The findings outlined the specifics of modern approaches to the development of technical and tactical skills. T. Peric *et al.* (2026) investigated the relationship between cognitive functions and the level of proficiency of jiu-jitsu athletes using virtual reality technologies. Attention, information processing speed and decision-making were assessed. The results demonstrated a correlation between cognitive indicators and the effectiveness of technical and tactical actions. The study contributed to analysis of the role of mental processes in sporting activity. A study by I. Hinzburh & V. Tyshchenko (2023) demonstrated that jiu-jitsu training improves the physical fitness of cadets at educational institutions. The researchers observed improvements in strength, endurance, coordination, and speed-strength qualities. The authors emphasised that incorporating elements of jiu-jitsu into the educational process is an effective means of comprehensive physical development.

Y. Santos (2026) also investigated the evolution of teaching methods in jiu-jitsu, from traditional forms to modern pedagogical approaches. Changes in the content of the training process and in the methods of imparting technical knowledge were analysed. The transformation of the coach's role and the organisation of training was identified. The results reflected the dynamics of the development of methodological principles of training. The development of software for analysing technical and tactical actions in Brazilian jiu-jitsu was conducted by M.A. Ferreira dos Santos *et al.* (2024). The structure of indicators characterising the effectiveness of technical techniques and tactical decisions was determined. The results demonstrated the possibility of a systematic analysis of athletes' competitive performance. The studies reviewed focused primarily on individual components of training for Brazilian jiu-jitsu athletes, specifically physical, cognitive or methodological aspects, without integrating them comprehensively within a single system of technical and tactical analysis. A comparative analysis with Japanese jiu-jitsu has not been adequately covered, which has hindered an integrated interpretation of the differences in the training of athletes in different disciplines.

The study aimed to identify the characteristics of technical and tactical training for athletes in traditional and Brazilian jiu-jitsu. The objectives of the study were: to analyse the technical repertoire and determine the functional significance of the main groups of technical actions in traditional and Brazilian jiu-jitsu; to characterise tactical approaches in competitive activity; to compare the structure of the training process and identify differences in the prioritisation of technical, tactical and competitive training; to conduct theoretical modelling of an integrated system of technical and tactical training for athletes.

Materials and Methods

The study was conducted using a theoretical approach based on methods of systems analysis, comparison and scientific generalisation. The source base was formed through the targeted selection, analysis and systematisation of scientific studies devoted to the development of jiu-jitsu, the technical and tactical training of athletes, and the structure of competitive activity (Draeger, 1973; Gracie & Danaher, 2003; Hancock & Higashi, 2006). The analysis also included works highlighting the characteristics of the training process, as well as the physiological and technical-tactical aspects of athletes' preparation (Andreato *et al.*, 2013; Andreato *et al.*, 2017; Bradic & Callan, 2018). Studies that explored issues of tactical strategies, match structure and the specifics of competitive activity in combat sports were analysed (Sánchez García, 2018; Spanias *et al.*, 2022). Sources were selected based on criteria of scientific relevance, topicality and representativeness, considering their alignment with the subject of technical and tactical training for athletes and the specific features of the training process organisation.

The study was based on a structural analysis method, which was used to divide the technical and tactical training of athletes in traditional and Brazilian jiu-jitsu into separate structural components. The analysis was conducted by grouping the technical repertoire into main categories (throwing techniques, joint locks and chokeholds, holds, transitions between positions), followed by an examination of their role and place in training and competition. Within the framework of this method, the principles of technical skill development were also analysed, in particular the sequence of their acquisition and the degree of technical

variability (Gracie & Peligro, 2003; Giardullo *et al.*, 2026). A content analysis of the official competition rules of the International Brazilian Jiu-Jitsu Federation (2024) and the Ju-Jitsu International Federation (2024) was conducted. The analysis covered the system for evaluating technical actions, scoring criteria, permitted and prohibited techniques, the role of wrestling in the standing and ground positions, conditions for early termination of a bout, as well as time limits for positional control and ground fighting. Regulated methods of transition between match phases and the significance of positional advantage in the structure of competitive activity were emphasised. The units of analysis were technical actions, tactical models of match conduct, phases of wrestling, the structure of training sessions, the role of sparring and situational exercises, as well as the specifics of competition rules. The criteria for content analysis identified the dominant groups of techniques, the ratio of actions in the standing and ground positions, the functional purpose of the techniques, the nature of transitions between phases of the fight, the criteria for the effectiveness of technical and tactical actions, and the methods for achieving a competitive advantage. Additionally, an analysis was conducted of tactical models of competitive activity in traditional and Brazilian jiu-jitsu. The criteria for their analysis were methods of initiating an attack, features of positional control, the nature of transitions between phases of the bout, the making of tactical decisions under changing conditions of the fight, as well as options for concluding a technical action following the specifics of the competition rules. The term "traditional (Japanese) jiu-jitsu" was used as a generalised technical and methodological model of the classical Japanese schools that formed the basic principles of technical, tactical and practical training within the martial arts system. Within the scope of this study, this term was not equated with the modern sport form of jiu-jitsu, but was considered as a set of traditional approaches to building a technical repertoire, organising the training process and developing combat skills.

A comparative analysis was used to systematically compare the content and organisational characteristics of training methods in Japanese and Brazilian jiu-jitsu. A comparison of the structure of training sessions was carried out, including the ratio of the preparatory, main and concluding parts, and differences in the prioritisation of technical, tactical and competitive training were identified (Ambroży *et al.*, 2021; Cerqueira *et al.*, 2022; Báez-San Martín *et al.*, 2025). A system of criteria was used, formulated in accordance with the key characteristics of the technical repertoire and the structure of the training process, namely the priority of technical groups, the main phase of the fight, the role of the ground game, the structure of technical actions, the nature of transitions between techniques, the level of variability, tactical orientation and methods of ending the bout. Additionally, criteria related to the organisation of the training process were considered, in particular the structure of the session, the characteristics of the preparatory, main and concluding parts, the organisation of technical instruction, approaches to the development of tactical skills, as well as the role of sparring and situational exercises.

The method of theoretical modelling was used to develop a model of integrated technical and tactical training for athletes, combining elements of traditional (Japanese) and Brazilian jiu-jitsu. This model involved a synthesis of the structural order and basic technical fundamentals characteristic of the Japanese school with the variability, adaptability and developed system of positional control inherent in Brazilian jiu-jitsu. The model involved the use of combined training methods, including technical sequences, situational exercises and varied sparring, aimed at developing athletes' adaptive tactical thinking. Based on a synthesis of scientific approaches, a structured example of a training session was developed as a conceptual model for organising training. The results obtained were interpreted using a systems approach and a structural-functional approach, which involved viewing technical and tactical training as a hierarchically organised system of interrelated elements. The limitations of the study lie in its focus on the structured analysis and modelling of technical and tactical training without empirical verification of the proposed model's effectiveness in practical conditions.

Results

The analysis of the technical repertoire of traditional (Japanese) jūjutsu was based on the classical schools of "koryū jujutsu" (traditional schools of old-style jujutsu), whose technical system included throwing, joint-locking, choking, holding and striking techniques, designed for practical application in hand-to-hand and armed combat. It has been established that the technical repertoire of these schools was characterised by complexity, functional variability and the combination of different groups of techniques within a single system of combat training (Mol, 2001). The study established that the system of technical actions within this martial art has a clearly structured hierarchical nature and includes several interrelated groups: throwing techniques (nage-waza), holding and immobilisation techniques (osae-waza), joint-locking techniques (kansetsu-waza), choking techniques (shime-waza), as well as auxiliary striking actions (atemi-waza), which serve as preparatory or destabilising elements. The use of these terms was based on a related Japanese classification tradition, common in judo and other Japanese martial arts, and was applied exclusively as an analytical framework for systematising the technical repertoire, rather than as an identification of traditional jiu-jitsu with judo. This classification reflected not only the morphological differentiation of techniques but also their functional purpose, which was to gain control over the opponent, restrict their movement, and create the conditions for ending the bout (Draeger, 1973).

A defining feature of traditional jiu-jitsu is the predominance of standing grappling, which is due to both historical and cultural factors and the practical nature of this martial art. Throwing techniques form the central element of the technical repertoire and include a wide range of manoeuvres, in particular sweeps, leg sweeps, body throws, as well as sacrifice techniques aimed at unbalancing the opponent and placing them at a disadvantageous position. At the same time, throws not only serve to change the opponent's spatial position but also act as a means of initiating further control actions (Bradic & Callan, 2018). A fundamental component of the technical system is a focus on the continuity of movement and the rational use of the opponent's strength. This is reflected in the classic three-part structure of executing a technical action, which includes

the stages of disrupting balance (kuzushi), preparing to execute the technique (tsukuri) and the actual execution of the technique (kake). This sequence not only ensures the biomechanical efficiency of technique execution but also forms the basis for the development of coordination skills and a sense of timing and distance in athletes. The transition from one technical action to another is achieved using the inertial characteristics of movement, which minimises energy expenditure and increases the efficiency of technical combinations. Within the methodological framework of traditional (Japanese) jiu-jitsu under consideration, ground fighting is more often presented as a logical continuation of the action following a throw, rather than as a separate phase of the bout. In this context, holding techniques (osae-waza), joint locks (kansetsu-waza) and chokeholds (shime-waza) are used to achieve ultimate control over the opponent, restrict their movement and force them to cease resistance. The application of these technical actions is regarded as a component of a comprehensive system for neutralising the opponent, in which throwing and ground combat elements are functionally interrelated. At the same time, striking techniques (atemi-waza) perform a supporting function, helping to create favourable conditions for the execution of the main technical techniques, in particular by destabilising the opponent's position or distracting their attention (Hancock & Higashi, 2006). From a functional perspective, the technical repertoire of traditional jiu-jitsu, particularly in an applied and self-defence context, is characterised by a focus on rapidly establishing control over the opponent and effectively ending the bout using throwing, joint-locking, choking and immobilisation techniques. In the sporting versions of Japanese jiu-jitsu, the execution of such actions is largely determined by the rules of the specific discipline and the system for scoring technical actions. This causes a predominance of combination moves, within which individual technical elements are integrated into coherent movement patterns. In the training process, these techniques are organised into training programmes designed to ensure the gradual development of motor skills, technical precision and versatility in execution (Sánchez García, 2018). This approach involves the gradual increase in the complexity of technical actions, their repeated practice, and adaptation to various conditions of interaction with a partner.

A structural analysis of the technical repertoire of Brazilian jiu-jitsu has revealed its distinct functional focus on controlling the opponent, engaging in ground fighting, and achieving a gradual positional advantage – a focus that has emerged as a result of the evolution of this martial art within a competitive environment. The study established that the technical system is hierarchically organised and is based on a sequential transition from less advantageous to more dominant positions, followed by the conclusion of the bout. Within this system, technical actions can be classified into several interrelated groups: positional control (maintaining dominant positions), guard as a specific form of defensive-offensive interaction (closed, open and numerous variations thereof), as well as submissions, which include pain and choke holds (Gracie & Danaher, 2003). This classification reflects not only the structural organisation of the technical repertoire, but also its functional focus on the gradual subjugation of the opponent through control and restriction of their movement. The dominance of ground fighting is a defining characteristic of Brazilian jiu-jitsu, which determines the specifics of both the technical and tactical training of athletes (Stephenson & Rossheim, 2018). In Brazilian jiu-jitsu, actions aimed at taking the opponent to the ground and establishing control over their body through positional advantage are central. At the same time, standing wrestling is regarded primarily as a preparatory phase, the functional purpose of which is to create the conditions for transitioning to the ground or initiating offensive actions aimed at securing an advantageous position. In competitive practice, ground fighting is the main arena for realising an athlete's technical and tactical potential, as this is where control is established, an advantage is formed and finishing moves are prepared (Andreato *et al.*, 2017).

One of the key characteristics of the technical repertoire is its high degree of versatility and adaptability, which is reflected in the athlete's ability to make seamless transitions between different positions depending on the opponent's behaviour. The study established that the technical structure is based on the principle of dynamic interconnection of elements, within which guards, dominant positions and attacking actions form a single system. Transitions between these components are conducted continuously, forming complex combinations and chains of actions, where each subsequent technical element logically follows from the previous one. This approach ensures flexibility in technical thinking and can be used by the athlete to quickly change their tactical strategy depending on changes in the opponent's position and actions. The guard also takes on significance within the technical structure as a universal tool for defence and attack. It acts as an intermediate link between defensive and offensive actions, which can be used by the athlete to control distance, restrict the opponent's movements, and create conditions for transitioning to more advantageous positions or for directly executing submissions (Gracie & Peligro, 2003). The variability of the guard, in particular the existence of its numerous modifications, contributes to increasing the unpredictability of the athlete's actions and complicates the opponent's counterattacks. The functional logic underlying the structure of technical manoeuvres in Brazilian jiu-jitsu is defined by the sequence: positional advantage – stabilisation of control – finishing the fight. Control of position is regarded as a key prerequisite for the effective execution of attacking manoeuvres, as it ensures positional stability and minimises the risk of losing the initiative. The match is concluded by applying pain or choke holds, the effectiveness of which depends directly on the quality of prior control and the correct timing of the attack (Spanias *et al.*, 2022). Thus, the technical repertoire is characterised by a clear logical sequence and a focus on the rational use of strength and spatial capabilities.

During training, these technical components are practised using specialised methods, with situational exercises and variable (positional) sparring being central. This approach simulates typical competitive situations, helps develop decision-making skills under time and space constraints, and fosters the ability to adapt quickly to an opponent's actions. Another substantial aspect is the emphasis on repeated practice of technical movements in various variations, which helps automate motor skills and

improve their effectiveness in real combat situations (Andreato *et al.*, 2013). Thus, Brazilian jiu-jitsu is characterised by systematicity, hierarchical organisation and a high level of adaptability, which ensures effective ground fighting. Its distinctive features include the prioritisation of positional control, the fluidity of transitions between technical elements, and a focus on consistently gaining an advantage leading to the conclusion of the bout, which defines its uniqueness as a modern martial arts system.

A comparison of the technical repertoires of Japanese and Brazilian jiu-jitsu has revealed differences in the prioritisation of technical groups, stemming from the historical context of their development and the specific nature of competitive practice. Both styles were based on the principles of controlling the opponent, utilising their strength and the rationality of movements; however, the implementation of these principles differed in structure and content. Traditional jiu-jitsu was characterised by a priority on throwing techniques and a linear sequence of technical actions, whereas Brazilian jiu-jitsu demonstrated a focus on positional control, multi-level transitions and a highly adaptable technical repertoire (Table 1).

Table 1. A comparative analysis of the technical repertoire of traditional and Brazilian jiu-jitsu

Content analysis criteria	Traditional jiu-jitsu	Brazilian jiu-jitsu
Dominant groups of technicians	Throwing techniques, holds, pain-inducing and immobilising manoeuvres	Position control, guard, submissions, ground transitions
Critical phase of the fight	Stability, followed by a transition to control	Ground fighting and the battle for positional advantage
Balance between standing and ground techniques	Most of the action takes place in the standing position; the ground is used primarily to secure control.	Dominance of ground fighting and sustained positional control
Functional purpose of the techniques	Disruption of equilibrium, neutralisation and rapid establishment of control	Gradual dominant position and preparation for the submission
Nature of the transitions between the phases of the struggle	Smooth transition from the throw to the hold or the completion of the move	Seamless transitions between positions and technical movements
Structure of technical operations	Regulated and structured	Variative and adaptive
Features of tactical models	Emphasis on quickly concluding a technical move after the opponent has lost their balance	Emphasis on maintaining position, wearing down the opponent and seeking opportunities to secure a submission
Role of competition rules in shaping tactics	Limits on prolonged ground combat, with an emphasis on throwing and control techniques	Encouraging positional control, guard passes and active ground combat
Performance indicators for technical and tactical actions	Effectiveness of control, precision of technique execution, and completion of the attack	Accumulation of position points, maintaining dominant positions, and early termination of the bout

Source: compiled by the author based on International Brazilian Jiu-Jitsu Federation (2024), Ju-Jitsu International Federation (2024)

An analysis of the competition rules revealed that the rules of the fight significantly influenced the development of tactical patterns in the styles under study. In traditional jiu-jitsu, restrictions on prolonged ground fighting and an emphasis on throws and control techniques encouraged athletes to quickly unbalance their opponent, execute an effective throw, and immediately finish the technical manoeuvre. The tactical model in this case was geared towards quickly gaining an advantage and minimising protracted positional struggles. In Brazilian jiu-jitsu, the scoring system, based on awarding points for passing the guard, maintaining dominant positions and controlling the opponent on the ground, shaped a different nature of tactical behaviour. Athletes emphasised gradual positional advantage, control of the match's tempo, and creating submission opportunities. The absence of strict time limits on ground fighting encouraged the development of multi-stage tactical combinations, continuous transitions between positions, and highly adaptable technical manoeuvres. In traditional jiu-jitsu, throwing techniques, takedowns, and elements of standing control dominated, which corresponded to the practical nature of the training and the focus on quickly unbalancing the opponent. In Brazilian jiu-jitsu, the priority shifted towards ground fighting, where positional control, holds, and submissions were of key importance, reflecting the specific nature of the sporting format and competition rules. There were also differences in how techniques were used in the standing position and on the ground. In traditional jiu-jitsu, the standing position was the primary phase for executing technical manoeuvres, where throws were performed and the ground combat laid for subsequent control. The ground was regarded as a secondary phase, within which technical combinations were completed. In Brazilian jiu-jitsu, by contrast, the ground game constituted the central phase of the fight, where the majority of technical and tactical actions took place, whilst the standing position served as a transition to positional fighting. The level of variability and adaptability of technical actions in the styles studied was characterised by different structures. In traditional jiu-jitsu, technical actions were performed within defined combinations and sequences, which ensured the structure and predictability of the training process. In Brazilian jiu-jitsu, variability was a defining characteristic, manifested in the athletes' ability to alter technical actions depending on the situation, transition between positions, and combine various techniques in continuous motion. The results obtained demonstrated that the technical and tactical structure of traditional and Brazilian jiu-jitsu was shaped by different functional and competitive priorities. Traditional jiu-jitsu was characterised by the structured nature of its technical combinations, a focus on standing techniques, and an emphasis on quickly gaining control over the opponent. In Brazilian jiu-jitsu, the defining features were positional grappling on the ground, the variety of technical transitions, and the adaptability of tactical decisions during the bout.

A comparative analysis of the structure of the training process in Japanese and Brazilian jiu-jitsu has revealed

differences in the balance of training components, the organisation of technique instruction, and approaches to developing tactical skills. In traditional jiu-jitsu, the training structure was characterised by clear regulations and a sequence of stages, comprising a preparatory, main and concluding section. The preparatory section involved general fitness exercises and basic movements aimed at preparing for technical elements. The main part focused on the step-by-step practice of technical actions following the established form and sequence. The final part included exercises for recovery and consolidation of the material covered. In Brazilian jiu-jitsu, the structure of the sessions also included these parts, but their proportions were characterised by greater variability. The preparatory part included functional and specialised exercises, the main part combined technical training with practical application, and the concluding part could include additional rounds of sparring or recovery exercises (Table 2).

Table 2. A comparative analysis of the structure of the training process in jiu-jitsu

Criteria	Traditional (Japanese) jiu-jitsu	Brazilian jiu-jitsu
Lesson structure	Clearly defined, consistent	Versatile, flexible
Introductory section	General warm-up, basic movements	Functional and specialised exercises
Main section	Step-by-step practice of techniques	A combination of technique, situational drills and sparring
Conclusion	Recovery, generalisation	Rematches or additional rounds
Organisation of technical training	Standardised repetition	Flexible, adaptable implementation
Tactics formation	Rehearsal of specific scenarios	Scenario modelling and decision-making
Role of sparring	Auxiliary	Main
Scenario-based exercises	Limited use	Widespread use
Type of training	Structured, regulated	Dynamic, adaptive

Source: compiled by the author based on T. Ambroży *et al.* (2021), B.S. Cerqueira *et al.* (2022), E. Báez-San Martín *et al.* (2025)

The approach to teaching techniques differed in terms of its underlying principles. In traditional jiu-jitsu, training involved repeated practice of techniques with a gradual increase in difficulty, which ensured the standardisation of movements. In Brazilian jiu-jitsu, technical training was integrated with variable performance conditions, which involved adapting techniques to the opponent's actions and applying them in different situations (Giardullo *et al.*, 2026). Approaches to developing tactical skills also differed: in the traditional style, these were developed through practising specific scenarios, whereas in Brazilian jiu-jitsu, they were developed through simulating combat situations and making decisions under changing conditions. The role of sparring and situational drills reflected these differences: in traditional jiu-jitsu, sparring served a supporting function, whereas in Brazilian jiu-jitsu, it was a central element of the training process.

An analysis of tactical approaches in competitive practice identified typical patterns of combat that reflected the specific characteristics of the sporting versions of traditional (Japanese) and Brazilian jiu-jitsu. Within the sporting and competitive context of traditional jiu-jitsu, tactical behaviour was characterised by a focus on quickly establishing control through the initiation of active actions aimed at disrupting the opponent's balance, executing a throw, and subsequently applying control or finishing techniques. The sequence of actions was characterised by relative linearity, whereby each stage of the bout logically followed on from the previous one. In Brazilian jiu-jitsu, tactical models were formed on the basis of gradually achieving positional advantage, which involved progressively restricting the opponent's actions, controlling space and creating conditions for a subsequent attack or the execution of a submission. This model was characterised by a longer duration of execution, continuous transitions between positions, and the presence of alternative options for the development of the bout. Decision-making methods in different phases of the fight differed in nature and dynamics. In traditional jiu-jitsu, decisions were made within the framework of pre-determined technical and tactical schemes, which ensured the coordination of actions and their suitability for typical situations. In Brazilian jiu-jitsu, decision-making occurred in a changing environment, where the choice of actions depended on the current position, the opponent's reaction, and the possibility of transitioning to a more advantageous position. This necessitated constant adjustments to tactical behaviour and the use of alternative solutions within a single bout. Differences in the athletes' tactical behaviour were evident in the nature of their interaction with the opponent and the ways in which they exploited their advantage. In traditional jiu-jitsu, actions aimed at achieving a quick result through the effective use of the initial phase of the bout predominated. In Brazilian jiu-jitsu, tactical behaviour was characterised by a gradual approach, control of the pace of the fight, and the ability to maintain a positional advantage over a prolonged period. This approach involved a more flexible response to the opponent's actions and the use of various scenarios for the development of the bout. The interconnection between technique and tactics was evident in the mutual determination of the choice of technical actions and the methods of their application. In traditional jiu-jitsu, technique served as the basis for implementing specific tactical schemes, which limited variability but ensured the structure of actions. In Brazilian jiu-jitsu, technical elements were integrated into the tactical process as tools for achieving positional advantage, providing variation in their use depending on the situation. Thus, the interrelationship between technique and tactics in the two styles was characterised by different levels of flexibility and methods of integration into competitive activity.

Based on a synthesis of the results of the structured analysis conducted using the theoretical modelling method, a conceptual model of integrated technical and tactical training for athletes was developed, which combines the systemic characteristics of two approaches to wrestling. The model was constructed by abstracting the key

structural elements of technical and tactical training, followed by their integration and logical organisation into a coherent system that reflects the patterns of effective competitive performance. The modelling covered parameters such as the structure of the technical repertoire, the nature of dominant positions, the principles of constructing technical actions, and the specifics of transitions between different phases of the bout (Table 3).

Table 3. Integration of elements of traditional and Brazilian jiu-jitsu into the technical and tactical training programme for athletes

Model component	Training contents	Training elements	Practical implementation	Expected result
Basic and technical	Mastery of fundamental techniques (throws, holds, joint locks, chokeholds), development of coordination and technical precision	Technical routines (cata), isolated practice of techniques, repetitive exercises	Step-by-step learning: from simple to complex, with repeated practice and quality checks	Consistency in technical skills, precision and efficiency in executing techniques
Position-monitoring	Development of control skills in the standing and ground positions, maintaining dominant positions, and transitions between positions	Positioning exercises, simulated scenarios, ground combat drills	Practice of maintaining positions (mount, side control, etc.), transitions and maintaining balance	Ability to control an opponent and maintain the upper hand
Tactical and versatile	Development of flexible tactical thinking, a variety of techniques, and building combinations	Scenario-based exercises, varied tasks, technical and tactical combinations	Simulation of various fight scenarios, variation in the conditions under which techniques are performed	Adaptability, speed of decision-making, and effectiveness in changing circumstances
Competitive and integrative	Integrating technical and tactical actions into a coherent system of competitive activity	Varied sparring, test matches, and competitive formats	Sparring sessions with various objectives (positional, time-based, tactical)	Comprehensive competition readiness, effective application of skills
Transient-dynamic (integrating)	Seamless transitions between the stand-up and ground phases, as well as between techniques and phases of the fight	Combined exercises, circuit training, scenario-based drills	Practising transitions: throw → control → submission; guard → sweep → dominant position	Smoothness of technical movements, fluid transitions, and energy efficiency

Source: compiled by the author based on B. Szabó (2017), L. Lamas *et al.* (2024), M. Gomes *et al.* (2025)

The proposed model is based on a synthesis of the structural order and basic technical fundamentals inherent in traditional training approaches, combined with the variability, adaptability and sophisticated positional control system characteristic of modern competitive practices. Conceptually, the model envisages a combination of two complementary training vectors. On the one hand, this involves the development of clearly structured basic technical skills that ensure the stability and precision of technique execution. On the other hand, it involves developing the ability to apply techniques variably in the changing conditions of a match, which enhances the flexibility and effectiveness of tactical decisions. Structurally, the model comprises several interrelated components: basic-technical, positional-control, tactical-variational and competitive-integrative. The basic-technical component focuses on the formation of fundamental motor skills, the mastery of key technical elements, and the development of athletes' coordination abilities. The positional-control component involves mastering the principles of controlling an opponent in various phases of the bout, including both standing techniques and positional control on the ground. The tactical-variational component is aimed at developing the ability to flexibly combine technical actions, make quick decisions and adapt to an opponent's behaviour. The competitive-integrative component ensures the integration of acquired skills into a coherent system of competitive activity, which takes the form of test matches and varied sparring. The key principle of the model's operation is to ensure seamless transitions between different technical and tactical actions, achieved by integrating training elements into a single logical sequence. This involves developing athletes' ability to effectively combine standing actions with transitions to the ground, maintain positional control, and execute finishing techniques at the right moment. This approach contributes to increasing the versatility of training and ensures a higher level of adaptability in competitive conditions. The implementation of the model in the training process involves the use of combined training methods, including technical sequences aimed at practising basic elements; situational exercises that simulate typical competitive situations and promote the development of tactical thinking; and varied sparring, which ensures the integration of technical and tactical skills in dynamic combat conditions. The combined use of these methods creates the conditions for the development of athletes' adaptive tactical thinking, enhances their ability to make effective decisions, and optimises their technical and tactical training as a whole.

An example of implementing an integrated model of technical and tactical training for jiu-jitsu athletes can be presented in the form of a comprehensive training session lasting approximately 90 minutes, structured in accordance with the logic of the step-by-step development of technical skills, positional control, tactical versatility and their integration into competitive activity. Such a session aims to develop novice athletes' ability to transition effectively from standing techniques to ground control, followed by the execution of finishing techniques, as well as to foster adaptive tactical thinking in the context of dynamic interaction with an opponent. The preparatory part of the session, lasting 10-15 minutes, involves general fitness and specialised exercises aimed at improving the body's functional readiness for exertion. It includes elements of a dynamic warm-up, joint mobility exercises, as well as specific movements characteristic of jiu-jitsu, in particular, safety techniques during

falls, ground movement, bridges and technical lifts. This stage creates the conditions for the safe and effective execution of subsequent technical actions and, at the same time, lays the foundation for developing the skills to transition between the different phases of a bout.

The main part of the session begins with the basic technical component (approximately 20 minutes), during which key technical movements are practised. In particular, the focus is on executing throwing techniques with an emphasis on disrupting the opponent's balance, correctly initiating the move and completing the technical action, followed by a transition to ground control. Practice is conducted initially with minimal resistance from the partner, and subsequently with a gradual increase in resistance, which helps to develop stable motor skills and improve the accuracy of technique execution. The next stage involves the positional control component (approximately 15 minutes), aimed at developing the ability to maintain dominant positions and control the opponent. During this stage, elements of stabilising the body position on the ground are practised, in particular, maintaining positions such as side control and transitions to more advantageous positions, such as mount. A substantial aspect is the development of the ability to maintain control for a specified duration under active resistance from the partner, which brings training conditions closer to competitive activity. The tactical-variational component (approximately 20 minutes) involves the use of situational exercises that simulate typical match scenarios. Athletes perform tasks aimed at achieving a specific objective (for example, transitioning to a dominant position or executing a submission) whilst facing active resistance from an opponent. This approach develops the ability to make decisions in dynamic situations, to diversify technical manoeuvres, and to adapt to changing circumstances during combat.

The transitional-dynamic component (approximately 10 minutes) is designed to integrate individual technical elements into coherent combination sequences. In this context, the connections between technical actions are practised, encompassing the sequence: taking the opponent to the ground, establishing control, and finishing the bout. The exercises are performed as continuous movement with a gradual increase in resistance, which helps develop the ability to transition smoothly between different phases of the bout and optimise energy expenditure. The competitive-integrative component (10-15 minutes) takes the form of varied sparring, during which athletes apply the technical and tactical skills they have acquired in conditions as close as possible to those of a competition. A distinctive feature of the stage is the ability to vary the starting conditions of the bout (starting from a standing position or on the ground, time limits or restrictions on technical actions), which can be used for a targeted influence on the development of specific aspects of training. The final part of the session (5-10 minutes) includes recovery exercises, stretching of the main muscle groups and a brief analysis of the combat. The reflective component helps athletes become aware of actions, identify typical mistakes and determine areas for further improvement. The proposed example of a training session demonstrates the practical implementation of an integrated model of technical and tactical training, within which a gradual transition is ensured from the acquisition of basic technical elements to their comprehensive application in competitive activity.

Discussion

The results of this study showed that traditional jiu-jitsu is characterised by greater structure, linearity and a focus on throwing techniques, whereas Brazilian jiu-jitsu is distinguished by high variability, adaptability and a predominance of positional control on the ground. This is consistent with the findings of R. Matkarimov *et al.* (2024), who noted that the effectiveness of technical and tactical training in martial arts depends on the ability to combine structured technical elements with adaptive tactical decisions. The results showed that in Brazilian jiu-jitsu, the athlete's ability to react quickly and maintain control in conditions of variable interaction with an opponent is substantial, as evidenced by continuous transitions between positions. This is consistent with the findings of J. Kędziorek *et al.* (2025), who established the significance of reaction and postural control under dual-load conditions in Brazilian jiu-jitsu athletes, emphasising the importance of sensorimotor adaptation for effective technical and tactical performance. The study also revealed that the training process in traditional jiu-jitsu is based on the standardised repetition of techniques and the practising of specific scenarios, which ensures consistency in performance. The results of this study showed that, in contrast to a more regimented approach, Brazilian jiu-jitsu favours the use of situational drills and sparring, which ensure constantly changing conditions and encourage athletes to make independent decisions. This approach promotes the development of adaptive thinking, the ability to react quickly to an opponent's actions, to vary technical manoeuvres and to combine them effectively in the dynamic environment of combat.

Tactical behaviour in traditional jiu-jitsu is linear in nature and aimed at achieving a result quickly, whereas in the Brazilian style it is characterised by gradual progression, positional control and flexible decision-making. This corresponds with the findings of L. Lorenço-Lima *et al.* (2025), who emphasised the role of mental resilience and cognitive flexibility in shaping effective behaviour in athletes under challenging competitive conditions. The study established a correlation between technique and tactics, which in traditional jiu-jitsu is more rigidly regulated and implemented through pre-determined technical and tactical patterns, whereas in Brazilian jiu-jitsu, it is characterised by flexibility, dynamism and the ability to constantly adapt in the context of changing interactions with the opponent. This approach involves not only the mechanical execution of technical actions but also their conscious variation depending on the situation during the bout, ensuring a more effective integration of the technical and tactical components of performance. This is consistent with the findings of L. de Lorenco-Lima *et al.* (2025), who highlighted the significance of self-control, aggression and psychological resilience as key factors ensuring athletes' performance in complex and dynamic competitive situations. The results of this study also showed that the use of varied sparring as a key element of training in Brazilian jiu-jitsu creates the conditions for the holistic integration of technical and tactical skills in an environment that closely resembles competition. The variability of sparring conditions, in

particular changes in starting positions, pace and level of resistance, helps to foster flexible thinking, improve decision-making skills and develop the ability to act effectively in non-standard situations. This training format not only enhances technical and tactical proficiency but also maintains a high level of athlete engagement in the preparation process. This is consistent with the findings of T.L. Tarver & J.J. Levy (2023), who noted that athletes' motivation to train is largely linked to practical forms of interaction, particularly sparring, which enhances the effectiveness of learning and skill consolidation.

The results of this study showed that the effectiveness of technical and tactical training depends not only on physical and technical aspects, but also on psychological factors. This is consistent with the findings of R.O. Segovia *et al.* (2024), who notes the positive impact of Brazilian jiu-jitsu training on mental health, as well as with the results of J.C.A. Bueno *et al.* (2025), who highlighted the importance of recovery and the physiological condition of athletes. The results of this study showed that the intensity and contact nature of Brazilian jiu-jitsu require proper control of training loads, as the dominance of ground fighting and continuous technical and tactical actions is accompanied by demands on athletes' functional, strength and coordination fitness. This is consistent with the findings of C.R. Riquelme-Hernández *et al.* (2022), who, within the framework of a scoping review, established that competitive activity in BJJ is characterised by high physiological and physical demands, as well as a significant role for technical and tactical components in the structure of athletes' sports training.

The results of the study showed that the high variability of technical actions and the dynamic nature of transitions between phases of a jiu-jitsu bout necessitate constant tactical decision-making and rapid decision-making under changing conditions of combat. In this regard, the effectiveness of technical and tactical actions depends to a large extent on the athlete's psychological resilience, their confidence in actions, and their readiness to apply varied models of match conduct. Effective technical and tactical training requires an adequate level of physical fitness and injury prevention, particularly in conditions of high-intensity combat and a significant number of ground-based contact actions. This is consistent with the findings of L.C. Nery *et al.* (2023), who identified a high prevalence of injuries among Brazilian jiu-jitsu athletes, particularly injuries to the knee and shoulder joints, which underscores the need for effective load management and the implementation of preventive measures within the sports training system. Positional control and ground combat in Brazilian jiu-jitsu are accompanied by increased stress on the musculoskeletal system, which influences the nature of athletes' training. This is consistent with the findings of M. Piekarski *et al.* (2026), who identified a high prevalence of knee injuries among athletes, emphasising the need to address biomechanical loads when planning the training process. Furthermore, the intensity of competitive activity and the specific nature of technical movements affect athletes' recovery process and necessitate a comprehensive approach to rehabilitation. The high level of physical contact, significant loads during ground fighting, and frequent transitions between positions create additional functional and mechanical stress on the body, requiring a systematic combination of recovery measures, load control, and rational planning of the training process. This is consistent with the findings of F. Santacaterina *et al.* (2025), who note that Brazilian jiu-jitsu is characterised by a high incidence of injury, which, in turn, necessitates the implementation of effective recovery strategies and the optimisation of the process of athletes' return to training and competition. Thus, the results of this study confirm that technical and tactical training in traditional and Brazilian jiu-jitsu have both common foundations and differences, which are manifested in the structure of technical actions, the organisation of the training process, and the tactical behaviour of athletes.

Conclusions

A comparison of the technical repertoires of Japanese and Brazilian jiu-jitsu has revealed differences in the priorities of technical groups, the structure and variety of technical manoeuvres, as well as in the roles of the standing and ground positions; these differences stem from the historical context of their development and the specific nature of their competitive practice. Both styles are based on shared principles of controlling the opponent and the rational use of movements; however, their practical implementation differs in terms of the content and structure of technical actions. Traditional jiu-jitsu was characterised by a dominance of throwing techniques, a focus on standing actions, and the linearity and structure of technical combinations, whereas Brazilian jiu-jitsu was distinguished by a focus on positional control on the ground, multi-level transitions, dynamism and a highly adaptable technical repertoire. A comparative analysis of the structure of the training process in Japanese and Brazilian jiu-jitsu also revealed differences in the balance of training components, the organisation of technical instruction, the development of tactical skills, and the role of sparring. In traditional jiu-jitsu, the training process was characterised by clear regulations, a sequence of stages, standardised repetition of techniques and the practising of specific tactical scenarios, which ensured the structure and predictability of the training. In contrast, Brazilian jiu-jitsu was characterised by diversity, a combination of technical training and practical application, the active use of situational drills, and the central role of sparring as the primary means of integrating technical and tactical actions. It was found that tactical behaviour in the traditional style was based on linear patterns aimed at achieving a quick result through the effective use of the initial phase of the bout. At the same time, in Brazilian jiu-jitsu, tactical models were based on the gradual acquisition of positional advantage, flexible responses to the opponent's actions, and the adaptability of decisions in changing combat conditions. This entailed a closer and more flexible interconnection between technique and tactics, ensuring the effectiveness of actions in various competitive situations.

Based on theoretical modelling, a conceptual model of integrated technical and tactical training for athletes has been developed, combining the structured and fundamental nature of traditional approaches with the variability, adaptability and positional control of modern competitive practices. The model encompasses interrelated components (basic-technical, positional-control, tactical-variational and competitive-integrative) and is based on the principle

of continuous transitions between technical and tactical actions, ensuring the integrity of training. Its implementation contributes to the formation of stable technical skills, the development of adaptive thinking, and the enhancement of athletes' competitive performance. The proposed example of a training session demonstrates the practical implementation of an integrated model of technical and tactical training, which ensures the step-by-step development of technical skills, positional control, tactical variability and their integration into competitive performance. The structure of the session involves a sequential transition from basic technique practice to their comprehensive application in conditions of variable interaction with an opponent, which promotes the development of adaptive thinking and the effectiveness of actions. The implementation of this model ensures the development of the ability to transition seamlessly between phases of a bout, the optimisation of technical and tactical actions, and an improvement in the performance of athletes in competition. Future research should verify the integrated model in practice and evaluate its impact on athletes' competitive performance.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Almeda, C.G., Mangine, G.T., Green, Z.H., Feito, Y., & French, D.N. (2023). Experience, training preferences, and fighting style are differentially related to measures of body composition, strength, and power in male Brazilian jiu-jitsu athletes: A pilot study. *Sports*, 11(1), article number 13. doi: 10.3390/sports11010013.

[2] Ambroży, T., Rydzik, Ł., Spieszny, M., Chwała, W., Jaszczur-Nowicki, J., Jekiełek, M., Görner, K., Ostrowski, A., & Cynarski, W.J. (2021). Evaluation of the level of technical and tactical skills and its relationships with aerobic capacity and special fitness in elite ju-jitsu athletes. *International Journal of Environmental Research and Public Health*, 18(23), article number 12286. doi: 10.3390/ijerph182312286.

[3] Andreato, L.V., Franchini, E., de Moraes, S.M., Pastório, J.J., da Silva, D.F., Esteves, J.V., Branco, B.H., Romero, P.V., & Machado, F.A. (2013). Physiological and technical-tactical analysis in Brazilian jiu-jitsu competition. *Asian Journal of Sports Medicine*, 4(2), 137-143. doi: 10.5812/asjsm.34496.

[4] Andreato, L.V., Lara, F.J.D., Andrade, A., & Branco, B.H.M. (2017). Physical and physiological profiles of Brazilian jiu-jitsu athletes: A systematic review. *Sports Medicine – Open*, 3(1), article number 9. doi: 10.1186/s40798-016-0069-5.

[5] Artyushenko, A., Verbytskyi, V., & Orlov, O. (2025). Peculiarities of the training methodology for 14-15 year old boys engaged in mixed martial arts. *Martial Arts*, 3(37), 70-76. doi: 10.15391/ed.2025-3.10.

[6] Báez-San Martín, E., Tuesta, M., Nieto-Jimenez, C., Ojeda-Aravena, A., Rojas-Valverde, D., Yáñez-Sepúlveda, R., & Alvear-Ordenes, I. (2025). Validity, reliability, and sensitivity of the Brazilian jiu-jitsu cardiorespiratory fitness test: A methodological approach based on combat specificity. *Applied Sciences*, 15(20), article number 11124. doi: 10.3390/app152011124.

[7] Bradic, S., & Callan, M. (2018). Critical judo elements in self-control development and emotional control. In *Proceedings of the 5th European science of judo research symposium* (pp. 23-27). Poreč: University of Zagreb.

[8] Bueno, J.C.A., Silva, R.B., Flores, M.A., & Andrade, A. (2025). Effects of rapid weight loss on sleep in Brazilian jiu-jitsu athletes: A pilot study with a case series. *Sport Sciences for Health*, 21, 2805-2811. doi: 10.1007/s11332-025-01484-w.

[9] Cerqueira, B.S., Cerqueira, M.B., Ferreira, W.C., de Oliveira, F.M., dos Santos-Júnior, R.B., Valdés-Badilla, P., & Branco, B.H.M. (2022). Proposal of a normative table for classification of body fat percentage in Brazilian jiu-jitsu athletes. *International Journal of Morphology*, 40(1), 57-61.

[10] de Lorenco-Lima, L., Gaines, S.A., & Waterbury, E.M. (2025). Aggression, self-control, life satisfaction, and resilience as predictors of mental health in Brazilian jiu-jitsu athletes. *Frontiers in Sports and Active Living*, 7, article number 1692536. doi: 10.3389/fspor.2025.1692536.

[11] Draeger, D.F. (1973). *Classical bujutsu: The martial arts and ways of Japan (Vol. 1)*. Boulder: Weatherhill.

[12] Ferreira dos Santos, M.A., Soto, D.A.S., Fernandes, J.R., Brito, C.J., Aedo-Munoz, E., & Miarka, B. (2024). Frami-software for Brazilian jiu-jitsu: Development and validation of the protocol for technical-tactical analysis. *Ido Movement for Culture: Journal of Martial Arts Anthropology*, 24(4), 16-25. doi: 10.14589/ido.24.4.3.

[13] Giardullo, G., Ceruso, R., Di Lascio, G., Taleb, M., Esposito, G., & D'Elia, F. (2026). Comparison of traditional and ecological dynamical training approaches in Brazilian jiu-jitsu: effects on force development, reactivity, and distress perception. *Frontiers in Psychology*, 17, article number 1794709. doi: 10.3389/fpsyg.2026.1794709.

[14] Gomes, M.S.P., da Silva Mocarzel, R.C., de Paula Machado Pasqua, L., Avelar-Rosa, B., & Correia, W.R. (2025). Diverse dimensions of Brazilian martial arts and combat sports: Exploring history, sociocultural impact, and educational integration. In A.R. Rodríguez-Sánchez, J. Piedra & G. Jennings (Eds.), *Martial arts in Latin societies* (ch. 3). London: Routledge. doi: 10.4324/9781032648620-5.

[15] Gracie, R., & Danaher, J. (2003). *Mastering jujitsu*. Champaign: Human Kinetics.

[16] Gracie, R., & Peligro, K. (2003). *Brazilian jiu-jitsu: Submission grappling techniques*. Montpelier: Invisible Cities Press.

[17] Hancock, H.I., & Higashi, K. (2006). *The complete Kano jiu-jitsu (judo)*. Mineola: Dover Publications.

[18] Hanley, B. (2023). *Brazilian jiu jitsu & mental resilience*. (Doctoral dissertation, University of Washington Tacoma, Tacoma, The United States of America).

[19] Hinzburh, I., & Tyshchenko, V. (2023). Jiu-jitsu as a means of increasing the level of physical fitness of cadets of higher education institutions of the Ministry of Internal Affairs of Ukraine. *Martial Arts*, 2(28), 26-35. doi: 10.15391/ed.2023-2.03.
[20] International Brazilian Jiu-Jitsu Federation. (2024). *IBJJF rules book (Version 6.0)*. Rio de Janeiro: International Brazilian Jiu-Jitsu Federation.
[21] Jones, C., Tsypkin, J., Saib, R., & Williams, J. (2026). Coaching Brazilian jiu-jitsu. In S.M. Smith (Ed.), *Ecological dynamics in sport coaching: An essential guide* (ch. 12). New York: Routledge. doi: 10.4324/9781003529972-15.
[22] Ju-Jitsu International Federation. (2024). *JJIF Jiu-Jitsu rulebook (Version 2.5)*. Retrieved from https://gbjj.co.uk/wp-content/uploads/2024/05/JJIF-Jiu-Jitsu-Rulebook-v2.5.pdf.
[23] Kędziorek, J., Błażkiewicz, M., Wąsik, J., Szopa, J., & Sołdacka, A. (2025). Reaction time and postural control under dual-task conditions in Brazilian jiu-jitsu athletes. *Applied Sciences*, 15(7), article number 3877. doi: 10.3390/app15073877.
[24] Lamas, L., Heiner, M., Ferreira, M., Moura, A., Rangel, W., Fellingham, G., & Lage, V. (2024). No-gi Brazilian jiu-jitsu: A Markovian analysis of elite-level combat dynamics. *International Journal of Sports Science & Coaching*, 19(4), 1767-1775. doi: 10.1177/17479541231210979.
[25] Lorenço-Lima, L., Waterbury, E.M., & Gaines, S.A. (2025). Mental Strength Scale (MSS-9): Factor structure and reliability. *Journal of Human Sport and Exercise*, 20(4), 1413-1426. doi: 10.55860/4zqnaq61.
[26] Matkarimov, R., Adilov, S., Kerimov, F., Korobeynikov, G., Korobeinikova, L., Bakiev, Z., & Abduazimovich, K.A. (2024). Improving the technical and tactical characteristics of elite wrestlers. *Slobozhanskyi Herald of Science and Sport*, 28(4), 197-203. doi: 10.15391/snsv.2024-4.003.
[27] Mocherniuk, V.B., & Leitsyus, V.S. (2025). Teaching technical and tactical actions of grappling and jiu-jitsu at the stage of preliminary basic training. In *Proceedings of the conference "Sports training of young men and students in non-Olympic martial arts in an educational institution"* (pp. 20-21). Lviv: Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies Lviv.
[28] Mol, S. (2001). *Classical fighting arts of Japan: A complete guide to koryu jujutsu*. Tokyo: Kodansha International.
[29] Nery, L.C., Pelegrina Junior, C.C., Saragiotto, B.T., Scoz, R.D., Marson, R.A., Mendes, J.J.B., Ferreira, L.M.A., & Amorim, C.F. (2023). Prevalence and profile of musculoskeletal injuries in high-performance professional Brazilian jiu-jitsu athletes. *The Open Sports Sciences Journal*, 16. doi: 10.2174/1875399X-v15-e221226-2022-23.
[30] Peric, T., Novicichin, S., Rydzik, Ł., Wąsacz, W., Ambroży, T., & Ruzbarsky, P. (2026). Cognitive functions and skill level in Brazilian jiu-jitsu: An exploratory study using virtual reality. *Frontiers in Sports and Active Living*, 7, article number 1738534. doi: 10.3389/fspor.2025.1738534.
[31] Piekarski, M., Kreiswirth, E., Barber Foss, K., Jimenez, M.L., Myer, G.D., & Montalvo, A.M. (2026). Knee injury in competitive Brazilian jiu jitsu athletes: Implications for training. *Sports Health*. doi: 10.1177/19417381251400303.
[32] Riquelme-Hernández, C.R., Reyes-Barria, J.P., Herrera-Valenzuela, T., Zapata-Lamana, R., Reyes-Molina, D., & Cigarroa, I. (2022). Profile of the Brazilian jiu-jitsu fighter: Variables, techniques and instruments for measuring sports performance: A scoping review. *Retos*, 45, 351-363. doi: 10.47197/retos.v45i0.91024.
[33] Sánchez García, R. (2018). An introduction to the historical sociology of Japanese martial arts. *Martial Arts Studies*, 6, 75-87. doi: 10.18573/mas.64.
[34] Santacaterina, F., Tamantini, C., Camarro, G., Miccinilli, S., Bressi, F., Zollo, L., Sterzi, S., & Bravi, M. (2025). Is Brazilian jiu-jitsu a traumatic sport? Survey on Italian athletes' rehabilitation and return to sport. *Journal of Functional Morphology and Kinesiology*, 10(3), article number 286. doi: 10.3390/jfmk10030286.
[35] Santos, Y. (2026). The evolution of teaching methods in jiu-jitsu: From tradition to modern pedagogy. *RCMOS – Multidisciplinary Scientific Journal The Knowledge*, 6(1). doi: 10.51473/rcmos.v1i1.2026.2105.
[36] Segovia, R.O., Buelna, A., & Sunderman, B. (2024). An examination of studies related to Brazilian jiu-jitsu in enhancing mental and physical health among veterans and first responders: A scoping review. *The Sport Journal*.
[37] Spanias, C., Kirk, C., & Øvretveit, K. (2022). Position before submission? Techniques and tactics in competitive no-gi Brazilian jiu-jitsu. *Revista de Artes Marciales Asiáticas*, 17(2), 130-139. doi: 10.18002/rama.v17i2.7410.
[38] Stephenson, C., & Rossheim, M.E. (2018). Brazilian jiu jitsu, judo, and mixed martial arts injuries presenting to United States emergency departments, 2008-2015. *The Journal of Primary Prevention*, 39, 421-435. doi: 10.1007/s10935-018-0518-7.
[39] Szabó, B. (2017). *Jujutsu: Its technical system and philosophy – research for Japanese cultural history*. Retrieved from https://budo-world.taiiku.tsukuba.ac.jp/en/2017/06/01/english-jujutsu-its-technical-system-and-philosophy-research-for-japanese-cultural-history-balazs-szabo-eotvos-lorand-university/.
[40] Tarver, T.L., & Levy, J.J. (2023). Brazilian jiu jitsu players' motivations to train. *Frontiers in Psychology*, 14, article number 1240351. doi: 10.3389/fpsyg.2023.1240351.

Порівняльний аналіз техніко-тактичної підготовки спортсменів у традиційному (японському) та бразильському джиу-джитсу

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Анотація. Метою дослідження було визначення специфічних характеристик техніко-тактичної підготовки спортсменів у традиційному та бразильському джиу-джитсу. Методологія дослідження ґрунтувалася на застосуванні структурного аналізу, порівняння та теоретичного моделювання. У результаті дослідження було встановлено відмінності у структурі технічного арсеналу двох стилів, що проявлялися у пріоритеті кидкової техніки, лінійності та регламентованості дій у традиційному джиу-джитсу та орієнтації на позиційний контроль, варіативність і адаптивність у бразильському. Виявлено, що у традиційному (японському) джиу-джитсу домінує стійка як основна фаза реалізації технічних дій, тоді як у бразильському ключову роль відіграє партер. Визначено відмінності у формуванні тактичних навичок, що проявляються у лінійності тактичних схем і орієнтації на швидке досягнення результату в традиційному стилі та у поступовому здобутті позиційної переваги, гнучкості та адаптивності рішень у бразильському. Обґрунтовано взаємозв'язок техніки та тактики, який у традиційному джиу-джитсу має більш жорстко регламентований характер, а у бразильському – динамічний і варіативний. Розроблено інтегровану модель техніко-тактичної підготовки, що поєднувала базово-технічний, позиційно-контрольний, тактико-варіативний і змагально-інтегративний компоненти, а також передбачала безперервність переходів між фазами поєдинку. Запропоновано приклад тренувального заняття, який демонструє практичну реалізацію моделі через поетапне формування навичок і їх інтеграцію у змагальну діяльність. Встановлено, що застосування варіативного спарингу та ситуаційних вправ сприяє розвитку адаптивного мислення та ефективності техніко-тактичних дій спортсменів. Результати дослідження підтвердили доцільність інтеграції структурованості традиційних підходів із варіативністю практик для підвищення ефективності техніко-тактичної підготовки спортсменів. Практичне значення дослідження полягає у можливості використання розробленої інтегрованої моделі та запропонованих тренувальних підходів для підвищення ефективності навчально-тренувального процесу спортсменів

Ключові слова: тренувальні засоби; процес підготовки; взаємозв'язок техніки та тактики; технічний арсенал; позиційний контроль

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 07.11.2025.Revised: 07.04.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.526:796.015
DOI: 10.69587/tppcs/1.2026.36

Features of the initial training stage of athletes in sport climbing

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Abstract. This study aimed to provide a theoretical justification for the specificities of physical and technical preparation of athletes at the initial stage of preparation in sport climbing. The study was based on the theoretical and methodological framework using theoretical analysis of scholarly sources and logical-structural modelling. The results showed that the training of novice athletes is multifaceted and based on the interconnection of physical qualities and technical skills. Among them, grip strength, coordination abilities and endurance are the priority ones. It is shown that grip strength can improve the athlete's ability to maintain positions in a variety of positions and transitions, and it is necessary to develop it with gradual changes, taking into account the physical possibilities of the athlete. It has been established that the coordination abilities play a system-forming function, as they ensure the correct mastery of technical movements, precision of movement and adaptation to track conditions. A review of the scientific literature has made it possible to select and substantiate such training methods and means: hanging and holding exercises, climbing on simple routes, balance and coordination exercises, as well as prolonged and interval adaptive workloads. It is also proven that the effectiveness of training at the initial stage can be ensured through the integrated implementation of these methods, variability of performing conditions and gradual complication of motor tasks. The developed model of the structural-logical structure of training has made it possible to establish the interrelationship between physical qualities and technical training, the development of coordination skills, and provided for the gradual development of motor skills. It was established that the rational regulation of the training load contributes to the safe preparation of sportsmen and the prevention of overload. The practical significance of the study lies in the possibility of applying its findings by coaches for sport climbing, teachers of physical education and instructors at children's and youth sport schools when organising training, in order to build the training process to ensure the correct and safe preparation of physical and technical qualities

Keywords: physical qualities; grip strength; endurance; training process; effectiveness of technical skill acquisition

Introduction

With the expansion of sport climbing into an Olympic discipline, the number of children and teenagers training systematically has grown, necessitating the scientifically grounded organisation of initial preparation. The initial phase of long-term athletic training plays a critical role in the formation of fundamental motor skills, coordination abilities, and prerequisites for further athletic improvement. Contemporary studies emphasise the necessity of

Suggested Citation: Dutko, T., Sokol, O., & Yakovenko, A. (2026). Features of the initial training stage of athletes in sport climbing. *Theory and Practice of Physical Culture and Sports*, 5(1), 36-46. doi: 10.69587/tppcs/1.2026.36.

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balancing general physical training with specialised training methods, while also accounting for the psychophysiological and developmental characteristics specific to youth athletes. The lack of a systematic approach to defining the content and organisation of the preparatory stage in sport climbing remains a significant obstacle to optimising training outcomes. It is substantiated that the organisation of initial preparation in sport climbing is related to the need to reconcile the goals of training in such aspects as the development of the main physical qualities and skills, acquiring skills, techniques and coordination skills, and maintaining the safety of training with children and adolescents. In practice, this creates a tension between the pressure to implement specialised skills from an early age and the age-appropriate recommendation to prioritise general physical development. These competing aims make identifying the optimal training structure for the early phase of sport climbing particularly challenging.

The impact of various training approaches on physical capacity and sport-specific performance has been explored by numerous scholars. For instance, N. Stien *et al.* (2023) evaluated the efficacy of combining specialised exercises with strength work within athlete training programmes. It was found that the integration of these methods leads to gains in strength, endurance, and skill execution efficiency. Furthermore, they noted that the training response differed based on the athlete's current level of conditioning, underscoring the need for differentiated training plans. The value of climbing movements for developing balance in youth was studied by M. Căsăneanu *et al.* (2025). They focused on the coordination-related aspects of motor activity. They measured static and dynamic balance under the influence of specially selected exercises. The researchers observed notable improvements in balance control, which they attributed to the unique movement patterns in climbing. These findings highlight the crucial contribution of such exercises to overall coordination development during childhood. In their research, B. Gilic & D. Vrdoljak (2023) investigated select preparation indices for young elite climbers with respect to their sex, age and biological maturity. They assessed the physical and functional qualities that determine performance in this sport. The differences found the strength, endurance and coordination indices according to the characteristics of the athletes. The study emphasised the necessity for taking into account individual physiological features in organising the training process in the initial period of preparation.

A. Saeterbakken *et al.* (2024) studied the relationship between strength training, climbing performance and injury prevention. They summarised the available evidence on the effect of various types of strength training on the performance indices of sport-specific and functional capacities of athletes. It is concluded that the presence of strength loads in the training process is associated with an increase in performance and a decrease in injury. P. Diez-Fernández *et al.* (2023) conducted a systematic analysis of the performance factors in sport climbing. Their study summarised data on the physical, technical and physiological qualities of athletes. They revealed strength, endurance and specific motor skills as key determinants of performance. The research also systematised approaches to performance assessment. K. Mulyk *et al.* (2021) assessed the efficiency of special equipment used for the development of muscular strength. They identified changes in strength characteristics as a result of using the training equipment of different types. The results obtained confirmed the role of technical training equipment in physical preparation.

M. Kovářová *et al.* (2024) performed an analysis of the injuries in climbing, taking into consideration risk factors. The study examined the types of injuries, their origin and training conditions. They also revealed the most common injuries and risk factors in the climbing process. The findings made it possible to reveal specific features of training organisation ensuring safety. M. Bingöl (2023) analysed the impact of climbing training on the physical qualities of athletes. The study examined the changes in strength, flexibility, speed and agility after undergoing a training programme. The group of study subjects showed the improvement of these indicators. The data obtained showed the effect of climbing training on the formation of physical qualities. H. Gürer *et al.* (2024) studied the effects of climbing training on psycho-emotional state in adolescents. The study analysed indices of mental health, emotional well-being and self-esteem. The researchers found changes in psychological qualities under the effect of climbing training.

The previously mentioned studies were limited to the investigation of specific components of preparation. They mainly focused on the formation of strength abilities, coordination abilities and psychophysiological characteristics. However, they failed to provide a detailed picture of the complex relationship between physical and technical preparation in initial training. At the same time, the systematisation of approaches to the development of grip strength, coordination and endurance abilities, including their inclusion into the structure of training, also requires further elucidation. This study aimed to establish the particular features of physical and technical preparation of novice athletes in the process of training in sport climbing. The objectives of the study included analysing scientific views on the content of physical and technical preparation of athletes in sport climbing, to identify means and methods of developing grip strength, coordination abilities and endurance at the initial stage of preparation and to construct a logical-structural model of athletes' initial preparation in sport climbing.

Materials and Methods

The study was conducted within a theoretical and methodological framework. The following methods were used: theoretical analysis of scholarly sources, the method of logical-structural modelling, and the method of systematic synthesis. The theoretical analysis of scholarly sources was carried out to determine the specific features of physical and technical preparation of athletes at the initial stage of preparation in sport climbing. The studies of C.M. Mermier *et al.* (2000) and E. López-Rivera & J. González-Badillo (2012) are used to identify the approaches to the development of grip strength and strength qualities, as well as the specifics of physical loads in climbing. The publications by S. Sterkowicz *et al.* (2014), D. Orth *et al.* (2016), and D. Saul *et al.* (2019) were used to describe coordination abilities, forming the motor actions and fundamental technical skills in novice athletes. The analysis of the articles by N. Taylor *et al.* (2020) and L. Rappelt *et al.* (2023) made

it possible to identify the most effective approaches to the development of endurance and ways of implementing adaptive forms of training loads. The units of analysis included types of physical qualities, methods of development and technical elements of sport climbing, methods of their development. The analysis allowed for the systematisation of the most common training methods used in the process of training. In particular, hanging and holding exercises, climbing on simple routes, coordination and balance, and adaptive forms of the interval and prolonged workloads.

To explore the theoretical principles in greater depth, the method of logical-structural modelling was used for the purpose of constructing the model of initial preparation in sport climbing. The model was developed on the basis of a synthesis of theoretical and methodological approaches to the preparation of athletes, as well as principles of sports training theory related to the stage-by-stage formation of motor skills and physical qualities development. The idea of the model was based on the interrelationship of physical and technical preparation, the priority of the development of coordination abilities during the initial stage of preparation, and the principles of progressive increase and variability of the training load. The model was built on the principle of sequential structuring, which involves the definition of training goals, followed by the selection of methods and means for achieving them. In the structure of the model, the main components were identified, namely: training objectives, leading physical qualities, methods of training influence, sequence of formation of technical skill, as well as the principles of load regulation. The logic of the model is based on a stageby-stage formation of motor skills, progressing from the acquisition of basic coordination elements to the integration of technical skills into the holistic activity of climbing. During the modelling, functional relationships between the level of development of physical qualities and the results of mastering climbing techniques were revealed, which allowed substantiating the priority of developing coordination abilities at the initial stage of athlete preparation, on which the formation of technique is based. The constructed model was theoretically verified by comparing the model units and logical basis of its construction with the data of the analysed sources (Vasile *et al*., 2021; Skriver *et al*., 2024). The interpretation of the results was based on the principles of the systems approach (initial preparation is an integrated dynamic system of interrelated factors: physical qualities, skills and technique; parameters of the training load). The obtained results created a theoretical basis for substantiating effective approaches to organising the training process at the initial stage of preparation in sport climbing and made it possible to identify optimal methods for developing key physical qualities and forming fundamental technical skills in novice athletes.

Results

The preparation of novice athletes in sport climbing is based on the integration of key physical qualities and technical skills. The structure of such preparation includes the main areas of development, namely grip strength, coordination abilities, endurance, and the formation of fundamental technical skills. One of the key areas in the preparation of athletes at the initial stage of training in sport climbing is the development of grip strength, as it is this that enables them to effectively maintain the body weight in interaction with the grips of different configurations and shapes, with different sizes and locations. In this regard, the development of both static and dynamic strength of the muscles of the hand, fingers and forearm is especially important, since this affects the ability of an athlete not only to hold the body position, but also to move from one position to another. An important aspect is also the development of grip endurance, which ensures the sustained maintenance of working capacity during route completion. At the initial stage of preparation, this component is developed gradually, taking into account the age-related and functional capacities of athletes, which makes it possible to avoid overload of the musculoskeletal system and ensure safe development (Labott *et al*., 2020; Buraas *et al*., 2025).

Coordination abilities are regarded as a system-forming component of preparation that determines the effectiveness of acquiring technical actions and the quality of movement execution. Their content includes the development of spatial-temporal accuracy, the ability to maintain balance in unstable positions, the differentiation of muscular effort, and the coordination of upper and lower limb movements (Orth *et al*., 2016). In sport climbing, coordination is manifested in the ability to position the body accurately in relation to supports, to change the position of the centre of mass in a timely manner, and to adapt movements to the specific features of the route. At the initial stage of preparation, one of the most important things is the development of coordination, since this lays the foundation for the formation of technique and the reduction of unnecessary energy consumption. In addition, a high level of coordination abilities contributes to increased training safety by ensuring movement control in complex positions (Sterkowicz *et al*., 2014). Within the system of preparation for novice athletes, endurance is understood as the body's ability to resist fatigue and maintain the required level of working capacity throughout the climbing process. Under the specific conditions of sport climbing, endurance has a complex character and combines both general and specialised endurance. General endurance creates the functional basis for performing prolonged workloads, whereas specialised endurance is directly associated with maintaining grip and repeatedly executing technical actions. A particular characteristic of the development of this component at the first stage is the implementation of adaptive load modes with a gradual increase in the duration and intensity of exercise (Saul *et al*., 2019). This ensures the balanced development of the body's functional capacities without the risk of overfatigue and contributes to improving the overall working capacity of athletes (Rappelt *et al*., 2023).

Technical preparation is an integrative component that brings together the results of physical development in the form of a holistic system of motor action. Its content implies mastery of key elements of movement along the route: the correct positioning of the feet, the most rational use of the holds, the best body position with respect to the vertical surface, and choosing a rational movement sequence. Special attention is paid to the development of skills aimed at economising motor activity, which involves reducing superfluous effort and distributing loads more rationally across different groups of muscles. Technical skills are

developed in the initial stage of preparation under simplified conditions, with a gradual increase in the level of complication of the tasks to ensure the acquisition of stable skills. At the same time, technical preparation has a close relationship with the development of coordination and strength, the joint improvement of which is necessary (Taylor *et al.*, 2020). In summary, each of the identified components performs a complementary function within the structure of athlete preparation at the initial stage, while their purposeful development provides the foundation for the further improvement of sporting mastery.

The process of formation and development of these components of the training of the athlete at the initial stage takes place under the systematic and consistent implementation of a number of specially selected methods, the purpose of which is the complex development of grip strength, coordination abilities, endurance and the most important technical skills. It was determined that the implementation of such an approach does not imply the use of individual isolated exercises, but the combination of a variety of exercises within the framework of a coherent training system. A characteristic feature of these methods is the variability of execution conditions, the gradual complication of motor tasks, and adaptability to the individual capacities of athletes, which ensures an optimal balance between educational and developmental effects. The development of grip strength takes place mainly through exercises on hanging and holding, during which the athlete maintains a stable body position on various types of holds (flat, active, passive, and crack holds) with different widths and positions of the fingers and hands, using different support points. The most common methods include hanging on straight and bent arms, maintaining a stable position of partial unloading of the lower limbs, as well as complex exercises with the transfer of load on the upper limbs from the minimum amount of load on the lower limbs to their gradual disengagement.

Key aspects that need to be taken into account include a gradual increase in the duration of the support, the use of repeated repetitions, the timing of the rest period and the maintenance of a certain degree of muscle tension. This type of training strengthens the muscles of the hand, fingers, and forearm, in addition to developing neuromuscular coordination. This enables the athlete to properly regulate effort and avoid excessive fatigue. This also increases the efficiency of acquiring technical skills. Climbing routes on simple routes is a fundamental tool for an integrated approach, combining the development of physical abilities with the acquisition of technical skills. At the initial stage, such routes should consist of a large, comfortable hold and a slight or vertical incline. It has a sufficiently complex sequence of movements. This creates favourable conditions for a more accurate execution of technical elements, particularly foot placement, choosing the best points of support and moving the body efficiently. Both methods are common in practice: ascent continuously in a steady rhythm, repetition in sections with a focus on learning separate movements. There was proof that such variability in conditions (change of rhythm of movement, conditions of restriction on the use of separate holds, movement from position holds) has a positive effect on the development of motor variability, increases the accuracy of performing movements and ability to act in changing environmental situations (López-Rivera & González-Badillo, 2012).

The exercises for developing balance and coordination are directed to develop the ability to maintain an equilibrium of the body and move effectively while performing complex supporting conditions. For these purposes, exercises on an unstable support are recommended, moving along a limited support, maintaining equilibrium in a standing asymmetrical position, and coordination exercises for changing body position under certain conditions. In the context of climbing, exercises with an emphasis on footwork are widely used, in particular, precise foot placement on small holds, shifting the centre of mass without using the hands, and performing movements with pauses in extreme positions. The use of such methods promotes the development of spatial awareness, improves intermuscular coordination, and supports the formation of rational movement strategies. Endurance development is achieved through the use of prolonged and interval training loads with an adaptive character, selected in accordance with the athletes' level of preparedness. Prolonged loads are implemented through continuous low-intensity climbing or sets of exercises with moderate intensity, which contribute to the development of general endurance and the functional capacity of the cardiovascular system. Interval training is based on the principle of alternating work-rest intervals, for example, by repeating the passing of sections of a route with a prescribed rest time. This ensures the development of a separate type of endurance and speed of recovery. When implementing this method, it is important to control the volume and intensity of training and, more importantly, gradually increase these parameters to ensure the quality of adaptation to training loads without overloading the athlete (Mermier *et al.*, 2000).

At the same time, it should be noted that these methods are not used independently of each other. This is part of a single process of sports training. Each of them has its own role here. It is both a specific as well as a complementary function. The combination of strength, coordination, and endurance exercises with technical tasks ensures the comprehensive development of athletes and creates the conditions for the formation of stable motor skills. It is also worth noting that at the initial stage, it is educational and developmental exercises that predominate, which contribute to the qualitative acquisition of fundamental elements, rather than achieving maximum indicators of the level of physical fitness. Consequently, the effectiveness of novice athlete preparation in sport climbing largely depends on the rational selection and combination of training methods that ensure gradual, safe, and diversified development of physical qualities and technical skills.

A structural-logical model of the initial stage of the preparation of athletes for sport climbing is presented. It shows how physical and technical preparation are interrelated in the process of learning. Physical preparation acts as the functional basis for the formation and implementation of technical actions. Meanwhile, technical preparation makes it possible to use the physical potential of the athlete more rationally during climbing. The main idea of the presented model is the priority development of coordination abilities at the initial stage of preparation, as it will affect the speed of formation of motor skills, the exactitude of the performance

of technical skills and adaptation to variable climbing conditions. This provides a basis for further development of grip strength, endurance, and technical skills of athletes.

The construction of the model was based on the principles of gradual progression and variability in training. The principle of gradual progress entailed the increase in the complexity of tasks and the volume of the training load step by step, depending on the level of training readiness. The principle of variability was realised through the variability of exercise conditions and the use of various work regimes, as well as taking into account the individual characteristics of the athletes in the training process. The training concept was based on the formation of motor actions in stages: the formation of elements of complex coordination was preceded by learning the basic technical movements of the activity, climbing. This principle ensured a stable nature of training and the formation of motor skills on a lasting basis. For a more systematic presentation of the content of the training process, its main components are presented with their structure and components depending on their functional goal in the training process, content and mechanisms of training are implemented (Table 1).

Table 1. Structure of the model of initial preparation for athletes in sport climbing

Model component	Content	Functional purpose	Expected outcome
Training objectives	Formation of a basic level of physical fitness and acquisition of fundamental technical skills	Define the overall direction of the training process and preparation targets	Achievement of an initial level of readiness for participation in climbing activities
Key physical qualities	Grip strength, coordination abilities, endurance	Provide the physical foundation for performing technical actions	Improved ability to maintain grip, coordinate movements, and sustain prolonged effort
Training methods	Hanging exercises, climbing on simple routes, coordination exercises, interval training loads	Deliver targeted development of physical qualities and technique	Formation of basic motor skills and development of physical capacities
Technical skills	Foot placement, use of holds, body positioning, movement sequencing	Integrate physical qualities into sport-specific motor activity	Development of an efficient climbing technique
Load regulation	Control of volume, intensity, and variability	Ensure adaptation and prevent overload	Gradual improvement in preparedness without excessive fatigue

Source: compiled by the authors based on data from A. Vasile *et al.* (2021), S. Skriver *et al.* (2024)

As the presented model suggests, initial preparation in sport climbing is a system, the physical training and technical training components of which are interrelated and interdependent. The presented components allow the formation of motor skills, taking into account an individual athlete's level of preparedness and the specificity of their activity. In the practical application of the model, the priority in the initial training was given to the development of coordination abilities as the basis for improving the technical skills of climbing, grip strength and special endurance. The efficiency of preparation is also related to the diversity of training methods and the appropriate dosage of the physical workload, which allows for a gradual adaptation of the athlete's body to the requirements of the activity, without any overloads. The resulting structure of the proposed model can be considered the theoretical and methodological basis for planning the training process of novice athletes in sport climbing and selecting the most appropriate methods for developing the necessary physical qualities and forming basic technical skills. Furthermore, in order to further develop the theoretical framework in order to improve the structure of the initial training, the functional relationships between key physical qualities and technical training in competitive rock climbing were analysed. The summary of the analysis allowed identifying that there is a specific effect of the coordination ability, strength of the hands, and endurance on the formation of technical skills in novice athletes. The corresponding functional relationships are presented in Table 2.

Table 2. Functional relationships between physical qualities and technical preparation of athletes at the initial stage

Physical quality	Nature of influence on technical preparation	Manifestation in climbing
Coordination abilities	Determine the speed and quality of acquiring technical elements; ensure precision and synchronisation of movements	Accurate body positioning, effective transfer of the centre of mass, adaptation to varying route conditions
Grip strength	Enables the execution of technical actions related to holding and transitions	Hold retention, positional stability, execution of dynamic transitions
Endurance	Influences the ability to maintain technical quality over extended periods	Sustained movement accuracy, reduced impact of fatigue, stability of technical actions

Source: compiled by the authors based on data from D. Stanković *et al.* (2019), R. MacKenzie *et al.* (2019)

t the first sub-stage, basic coordination skills development prevails, which provides for mastering basic methods of movement control, balance maintenance, and spatial orientation. During this period, attention is paid to the formation of simple motor actions and the development of proprioceptive sensitivity and control of the position of the body, as the foundation for subsequent steps to the more complex technical task. The following stage is characterised

by the gradual integration of established coordination elements with the development of strength and endurance, which makes it possible to master more complicated motor actions and withstand higher workload. At this level, the formation of motor skills of athletes occurs through an expansion of motor experience, an increase in the accuracy of execution of movements, and the ability to use them depending on the way they are carried out. The final stage of initial preparation is associated with the integration of developed physical qualities and technical training in the overall work of sport climbing, which is manifested in the ability to perform sequences of motor actions with the right technical execution and rhythm and with minimal effort. At this level, coordination movements become more organised, motor skills are better automated, and they are performed stably with variable loads. It is also proven that a step-by-step training is a prerequisite for forming motor skills correctly. This means that learning should have a logical course, and the tasks should increase gradually, while the physical and technical part of novice athletes should fit into the structure in the most effective way.

It is important to keep in mind that physical fitness acts not only as a condition that makes it possible to execute motor actions, but also as a factor that affects the quality, accuracy and stability of technical actions. Coordination abilities affect the development of technical skills, since they provide the accuracy of movements, coordination of movements in individual body parts, as well as the ability to quickly adjust motor programmes to certain conditions, that is, to certain tasks. The higher the level of coordination, the more quickly technical elements are learned, the more varied they are, and the smaller the costs of effort during the climb. Grip strength reflects the ability to perform technically associated actions; that is, it is possible to maintain a body position or change grips. A low level of grip strength does not allow technically correct movements to be effective; however, its gradual increase allows for an increase in the functional opportunities of the athlete and makes the execution of technical movements more reliable. Endurance acts as a factor that provides the stability of technical actions over time. A high level of endurance allows for the maintenance of movement accuracy during the exercise, prevents the occurrence of fatigue in an advanced manner and ensures that the required level of coordination and strength is maintained. All these relationships are interdependent, which means that, for example, the improvement of one component of physical fitness indirectly affects the development of other preparation components and the effectiveness of the technique. In particular, coordination allows the most efficient use of strength in the movements of climbing, while the development of endurance ensures the stability of the coordination of the actions of the climber for a long period of loading. Coordination plays a key role in the formation of the structure of the initial training of athletes, as they determine the speed and quality of mastering technical elements. A well-developed level of coordination ensures an accurate movement, effective balance and the correct use of physical effort during a climb. At the same time, grip strength and endurance form a functional basis of the stability of technical performance in the process of training. It has been established that the combined development of coordination abilities, grip strength and endurance provides effective formation of sports mastery in novice athletes.

At the first stage of preparation for sport climbing, it is necessary to use training means and techniques, which will contribute to the steady and gradual improvement of the basic physical qualities of the athlete, and the development of coordination abilities and skills. The main task at this stage is to form an adaptation of the body of an athlete to specific loads, to develop proper movement technique and provide conditions for safe work during training. In order to improve grip strength in sport climbing, exercises can be used, such as hanging on a large hold with a short-term fixing of the position and movement at low height hand grip exercises with an average level of resistance for finger fixation. It is necessary to do with small volumes and long rests, as it is important to avoid overworking the hands and fingers at the beginning. The volume can be increased by adding duration to the exercise, adding more reps, and then adding the more challenging kinds of holds. However, novice athletes should avoid campus board training, small holds, and exercises with added weight, as this puts athletes at a higher risk of ligament and tendon injuries. Coordination abilities can be improved as a result of exercises to maintain balance, tasks on orientation in the space, and exercises to synchronise movement. It is beneficial to use coordination ladders, perform balance exercises on unstable supports, climb routes without technical difficulty, while focusing on accurately placing the feet, and train with a steady movement tempo. At the initial stage, it is recommended to use simple routes and exercises without psychological stress in order to prevent height phobia and loss of control over the technique. Complexity can be raised by changing the features of the wall, adding more coordination elements, or doing exercises in non-standard positions. Endurance can be achieved by working at an average intensity, without reaching a state of marked exhaustion, for a long time. Methods could be extended to include climbing on easy routes, sets of traverses, running exercises, jump roping, and individual exercises of circuit-style training. It is suggested that novice athletes use an interval approach, performing exercises for short time periods and then resting for an adequate period of time. The workload can be gradually increased by extending the duration of exercises, increasing the number of reps, and reducing the rest between exercises. The workloads that are used at this age should not be too large and lead to complete fatigue due to the low level of physiological adaptation in young athletes.

Technical exercises for beginners include fixing the feet, transferring the centre of gravity, and maintaining the position of the body. These exercises help to master and improve their technique and at the same time economise energy. It would be good to start with learning movements gradually, having the teacher explain and show them, and doing these exercises at an easier level, increasing the level gradually until they move to the most difficult elements. Special attention should be given to learning the correct technique of movement along the track as the athlete first gains fundamental motor skills. The principle of individualisation of training and the safety of the training process are of primary importance for novice athletes in terms of learning climbing in general. Before starting the exercises,

it is recommended to do a full warm-up, and special emphasis should be put on the wrists, shoulders, and trunk. Training sessions should be organised on easy routes using reliable belay systems and certified equipment. In the first stages of training, the athlete is not recommended to perform movements of an intense nature, with high loads or a long static loading of one hand, in order to avoid overloads of the musculoskeletal system.

Discussion

The results of this study showed that the training of sports climbing is complex and is based on the interaction of physical and technical qualities. This is consistent with the results of S. Faggian *et al.* (2025), where they revealed the multifactorial nature of the sporting activity, focusing attention on the physical and technical components that make up the complex. It was further demonstrated in the study that a successful training process is formed due to the holistic interaction of the qualities and not by a separate, isolated study. This can be explained by the interrelated and interdependent impact of the strength, coordination, and endurance on the formation of technical perfection. It helps to make the performance of movements more rational and economical. This study has also shown that coordination abilities have a priority influence, which is consistent with the data of A. Kurniawan *et al.* (2026), where it is noted that balance and coordination are the basic abilities for effective climbing performance. The priority of the development of coordination abilities allows an improvement in movement accuracy, an increase in stability of the body, and an overall impact in terms of improving the quality of execution of motor actions. Coordination abilities are an important component of the process of mastering and formation of motor skills, which is consistent with the study of H. Zhang *et al.* (2026), where it was demonstrated that movement accuracy and control of the position of the body are key factors of the kinematics of performing a movement for climbing performance. Similarly, the study found that a high level of coordination contributes to adapting to different conditions of the route and saving energy. An important component of the preparation of novice athletes is the strength of grip, because holding the grip helps to maintain positions and perform transitions. This is in line with the results of K. Langer *et al.* (2023), who showed that the specific strength affects climbing performance. At the same time, the results of the current study showed that the development of strength should be done gradually, considering the age and functional characteristics of the athlete, as in the study of Z. Kozina *et al.* (2020), where they emphasised the importance of gradual progression of the physical qualities. The study specifies that staging the training process involves not only a gradual accumulation of loads but also changes in the conditions of performing exercises and a certain control over muscle tension, which makes it possible to avoid overloading the musculoskeletal system. In addition, authors stressed that the combination of different means within one system allows for a higher degree of sporting performance, which coincides with the data obtained in the present study.

Endurance in climbing has a complex character and includes both general and special components, which corresponds to the conclusions of M. Maciejczyk *et al.* (2022) regarding the participation of different energy systems in maintaining performance during the implementation of sport-specific exercises. The results obtained in the current study confirmed that a complex training method is more effective than individual isolated exercises. The technical preparation in climbing is an integrative part of a single motor system that unites different physical qualities, which is supported by the studies of F. García-Heras *et al.* (2025) on the importance of properly working with the lower extremities and a perfect technique of movements in the climbing process. In addition, the present study revealed that the efficient work of the lower extremities reduced the load on the upper limbs and improved the economy of movements, which is especially important at the beginning of the preparation process. It is this factor that determines the more efficient mastering of motor skills and the stability of the movement performance. The results of this study showed that different training conditions contribute to the improvement of adaptability of athletes, which is consistent with the conclusions of M. Turchetto *et al.* (2025) on the impact of experience, training frequency and psychological factors on the development of competence in the sport of climbing. The article also specifies that changes in the tempo, the position of support, and the execution of different elements in movement allow for improving the variability of motor activity and the ability to act in accordance with the changing conditions. As a result, this contributes to the development of stable motor skills and increases performance in the conditions of different routes. The importance of an individual approach to training was also noted in the current study, which corresponds to these conclusions. In addition, the study has shown that the appropriate dosing of loads is an important condition for effective training and prevention of injuries, which is confirmed by the conclusions of A. Obcowska *et al.* (2025) pointed out the risk of injury in climbing and the need to control training loads. The current study has also noted the need for a gradual increase in loads during training, which allows a safe training process and promotes the development of athletes. In addition, the presented study shows that coordination abilities perform a system-forming function in novice athlete preparation structure, which also matches the results of K. Nema *et al.* (2025), who reported a connection between levels of physical condition and performance of young athletes. This study additionally explains that the coordination component is an important factor in the effectiveness of other physical qualities. Prioritised development of coordination abilities leads to more rational formation of technical movements and reduced unnecessary energy costs. This also creates prerequisites for more effective development of grip strength and endurance because their realisation is also based on previously formed coordination abilities.

The results additionally indicate that at the initial stage, technical preparation should be implemented based on rational use of biomechanical movement principles, which also corresponds to the conclusions of S. Dech & R. Kittel (2026), who systematised the biomechanical bases of climbing technique and noted the need to create an effective distribution of loads along body segments. Also, this study shows that forming a rational body position and its sequence contributes to economising the activity, which also corresponds to the authors' opinion about optimising

the kinematic parameters of movements. The use of climbing as a universal means of training results in the comprehensive development of physical qualities and techniques, which also corresponds with the conclusions of W. Deng & D. Ding (2023), who reported the results that climbing is an effective means of physical training for athletes of various disciplines. Training in sport climbing at the stage of initial training contributes to the simultaneous formation of key motor abilities of the body and the improvement of its functional capabilities. The study also points out that this approach increases the efficiency of forming technical movements through the combined integration of motor and physical components of activity. The results also indicate that the step-by-step increase in the level of complexity of training tasks is a prerequisite for the formation of technical mastery, which also corresponds to the conclusions of A. Blay *et al.* (2025), who noted the need to improve techniques as a result of progressive changes in the complexity of technical movements. This provides the stability and accuracy of movements in climbing practice. It is also important to unite the separate components of the training system as a whole into a unified framework that allows for a more efficient training process, which corresponds with the conclusions of G. Levernier & G. Laffaye (2021), who noted that for a more comprehensive study and development of the athletes' level of preparedness, it is necessary to implement a combined approach of training and testing. Such an approach is especially important at the initial stage of training, when the foundations for future athletic development are being laid. Therefore, the present study's outcomes not only validate the mentioned scientific approaches but also expand upon them, specifically concerning the early phases of sport climbing training, with a focus on movement biomechanics, the combined nature of training outcomes and stages of the technical preparation.

Conclusions

The results of the theoretical analysis show that the preparation of novice athletes for sport climbing consists of the joint development of physical qualities and techniques. The major blocks in its structure are the development of grip strength, coordination abilities, endurance and formation of basic technical skills. Grip strength is one of the main components, as it ensures support of the athlete's body in the ascent and the performance of motor skills with a static and dynamic muscle effort. Coordination abilities are a system-forming component; they determine the quality of movement technique, effectiveness and safety of the process of training. Their development establishes the foundation for efficient movement and reduced energy expenditure. Endurance is regarded as a complex quality that combines general and specific qualities through the progressive growth of physical activity. Technique preparation consists of the complex use of the physical qualities in the system of movements, and the acquisition of basic elements of climbing in a dynamic, progressive manner. The mentioned components are connected and interwoven with each other and provide mutual support. Their focused development lays the groundwork for the further improvement of sporting achievements.

Development of training components at the first stages of sport climbing training is implemented through the systematic use of special methods that ensure the combined development of grip strength, coordination ability, endurance, and technique. The effectiveness of training at the first stages is ensured through the integrated use of exercises, their connection with each other, and a certain logic of training content. The characteristics of the above-mentioned methods are their variability, progressive training tasks and adaptation to the individual characteristics of athletes. Grip strength is developed through exercises in hanging and static holding, in which variation of exercise conditions is used, thus strengthening the muscles of the athlete and developing coordination abilities. Basic training method to develop the technical skills and physical qualities is climbing along routes of low difficulty. Variation in execution conditions contributes to the development of movement accuracy and adaptive capacity. Methods to develop balance and coordination are performed to improve equilibrium and orientation in space, and efficient movement.

Based on the results of the theoretical analysis, a structural and logical model of the initial stages of preparation for sport climbing was developed, which shows the interconnection of the main blocks of preparation. On the theoretical basis of a systemic approach, the unity of technical and physical preparation is assumed, where physical qualities are the foundation, and technique training is the connecting element. In this model, the priority is given to coordination, which ensures the effective technique of movement and adaptation to the conditions of climbing. It is considered that the development of coordination is the most important condition for effective grip strength and endurance training, as well as technical preparation. The model is based on the principles of progression and variability, which provide for a step-by-step change of the tasks and adaptation of the load to the characteristics of athletes. A key condition of the formation of motor actions is the sequential process from simple techniques to complex ones. The proposed model includes the training tasks, physical qualities, types of exercises, motor techniques and load management. All the elements of the structure, in one way or another, play a special role and are oriented towards the achievement of the initial level of training readiness. The interrelationship of structural and logical model components creates an integrated process. Implementation of the model leads to the effective training of the necessary motor skills and basic physical qualities, and provides for a lack of overload in training. It has been established that a close functional relationship exists between physical qualities and technical preparation in novice athletes. In the future, there is a perspective to study the effectiveness of the proposed model in the course of the experimental study, to improve the methodology of training coordination, grip strength and endurance of novice athletes.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Bingöl, M. (2023). Investigation of the effect of sport climbing training on some physical parameters of athletes. *Revista de Gestão e Secretariado*, 14(10), 17835-17844. doi: 10.7769/gesec.v14i10.3001.

[2] Blay, A., Baudinet, I., & Clément, J. (2025). Performance analysis in speed climbing among developing athletes. *Multidisciplinary Biomechanics Journal*, 2, 457-459. doi: 10.46298/mbj.16168.

[3] Buraas, B.F., Brobakken, M.F., & Wang, E. (2025). Climbing performance in males: The importance of climbing-specific finger strength. *European Journal of Applied Physiology*, 125, 2823-2830. doi: 10.1007/s00421-025-05802-5.

[4] Căsăneanu, M., Mihăilescu, L.N., Potop, V., Mihăilă, I., Manole, C., Mihăilescu, L.E., Rață, B.C., Mâță, L., & Rață, M. (2025). The role of climbing exercises in developing balance ability in children. *Applied Sciences*, 15(11), article number 5959. doi: 10.3390/app15115959.

[5] Dech, S., & Kittel, R. (2026). Biomechanical principles and techniques – a systematization for sport climbing. *Journal of Functional Morphology and Kinesiology*, 11(1), article number 103. doi: 10.3390/jfmk11010103.

[6] Deng, W., & Ding, D. (2023). Rock-climbing exercise in the physical training of athletes. *Revista Brasileira de Medicina do Esporte*, 29, article number e2022_0672. doi: 10.1590/1517-8692202329012022_0672.

[7] Diez-Fernández, P., Ruibal-Lista, B., Rico-Díaz, J., Rodríguez-Fernández, J.E., & López-García, S. (2023). Performance factors in sport climbing: A systematic review. *Sustainability*, 15(24), article number 16687. doi: 10.3390/su152416687

[8] Faggian, S., Borasio, N., Vecchiato, M., Gatterer, H., Burtscher, M., Battista, F., Brunner, H., Quinto, G., Duregon, F., Ermolao, A., & Neunhaeuserer, D. (2025). Sport climbing performance determinants and functional testing methods: A systematic review. *Journal of Sport and Health Science*, 14, article number 100974. doi: 10.1016/j.jshs.2024.100974.

[9] García-Heras, F., Diez-Martín, M., González-Martín, D., Gutiérrez-Arroyo, J., Molinero, O., & Salguero, A. (2025). Analysis of lower limb performance determinants in sport climbing. *Applied Sciences*, 15(16), article number 8797. doi: 10.3390/app15168797.

[10] Gilic, B., & Vrdoljak, D. (2023). Sport-specific performances in elite youth sport climbers: Gender, age, and maturity specifics. *Biomedical Human Kinetics*, 15(1), 49-56. doi: 10.2478/bhk-2023-0007.

[11] Gürer, H., Akçınar, F., Arslan, S.C., Akçınar, S., Güllü, M., Eken, Ö., Kurtoğlu, A., Ilkım, M., Alotaibi, M.H., & Elkholi, S.M. (2024). Evaluating the impact of rock climbing on mental health and emotional well-being in adolescents. *Frontiers in Psychology*, 15, article number 1426654. doi: 10.3389/fpsyg.2024.1426654.

[12] Kovářová, M., Pyszko, P., & Kikalová, K. (2024). Analyzing injury patterns in climbing: A comprehensive study of risk factors. *Sports*, 12(2), article number 61. doi: 10.3390/sports12020061.

[13] Kozina, Z., Uvarova, N., Cieslicka, M., Bejtka, M., & Jagiełło, M. (2020). Experimental substantiation of the program of the annual cycle of preparation of climbers 16-17 years to the competitive discipline "climbing combined". *Journal of Physical Education and Sport*, 20(2), 1250-1256. doi: 10.7752/jpes.2020.s2174.

[14] Kurniawan, A., Murtono, T., Usbah, M., & Liloi, D.K. (2026). Development of a balance training model in wall climbing games in the Palado organization in Pulu City, Sigi Regency. *COMPETITOR: Jurnal Pendidikan Kepelatihan Olahraga*, 18(1), 1696-1706. doi: 10.26858/cpjok.v18i1.676.

[15] Labott, B.K., Held, S., & Donath, L. (2020). Grip strength-endurance in ambitious and recreational climbers: Does the strength decrement index serve as a feasible measure? *International Journal of Environmental Research and Public Health*, 17(24), article number 9530. doi: 10.3390/ijerph17249530.

[16] Langer, K., Simon, C., & Wiemeyer, J. (2023). Strength training in climbing: A systematic review. *Journal of Strength and Conditioning Research*, 37(3), 751-767. doi: 10.1519/JSC.0000000000004286.

[17] Levernier, G., & Laffaye, G. (2021). Rate of force development and maximal force: Reliability and difference between non-climbers, skilled and international climbers. *Sports Biomechanics*, 20(4), 495-506. doi: 10.1080/14763141.2019.1584236.

[18] López-Rivera, E., & González-Badillo, J.J. (2012). The effects of two maximum grip strength training methods using the same effort duration and different edge depth on grip endurance in elite climbers. *Sports Technology*, 5(3-4), 100-110. doi: 10.1080/19346182.2012.716061.

[19] Maciejczyk, M., Michailov, M.L., Wiecek, M., Szymura, J., Rokowski, R., Szygula, Z., & Beneke, R. (2022). Climbing-specific exercise tests: Energy system contributions and relationships with sport performance. *Frontiers in Physiology*, 12, article number 787902. doi: 10.3389/fphys.2021.787902.

[20] MacKenzie, R., Monaghan, L., Masson, R.A., Werner, A.K., Caprez, T.S., Johnston, L., & Kemi, O.J. (2019). Physical and physiologic determinants of rock climbing. *International Journal of Sports Physiology and Performance*, 15(2), 168-179. doi: 10.1123/ijspp.2018-0901.

[21] Mermier, C.M., Janot, J.M., Parker, D.L., & Swan, J.G. (2000). Physiological and anthropometric determinants of sport climbing performance. *British Journal of Sports Medicine*, 34, 359-365. doi: 10.1136/bjsm.34.5.359.

[22] Mulyk, K., Grynova, T., Skaliy, A., Bershov, S., & Kornienko, V. (2021). Level of strength development of students involved in rock climbing sports sections using exercises on different simulators. *Sport Herald*, 9(5), 5-15.

[23] Nema, K., Gilic Skugor, B., Vrdoljak, D., Kozák, T., Berta, P., & Kováč, M. (2025). Physical fitness of elite youth sports climbers: Gender differences and correlates of climbing ability. *Biomedical Human Kinetics*, 17(1), 197-207. doi: 10.2478/bhk-2025-0019.

[24] Obcowska, A., Duda, J., Kędzia, J., Walendzik, A., Racisz, P., Obcowska, K., & Racisz, K. (2025). Sport climbing and bouldering: Injury patterns with focus on the lower extremities. *Quality in Sport*, 47, article number 66722. doi: 10.12775/QS.2025.47.66722.

[25] Orth, D., Davids, K., & Seifert, L. (2016). Coordination in climbing: Effect of skill, practice and constraints manipulation. *Sports Medicine*, 46, 255-268. doi: 10.1007/s40279-015-0417-5.
[26] Rappelt, L., Rein, R., Wiedenmann, T., Held, S., & Donath, L. (2023). Low-intensity climbing with blood flow restriction over 5 weeks increases grip and elbow flexor endurance in advanced climbers: A randomized controlled trial. *European Journal of Sport Science*, 23(10), 2031-2037. doi: 10.1080/17461391.2023.2207079.
[27] Saeterbakken, A.H., Stien, N., Pedersen, H., Langer, K., Scott, S., Michailov, M.L., Gronhaug, G., Baláš, J., Solstad, T.E.J., & Andersen, V. (2024). The connection between resistance training, climbing performance, and injury prevention. *Sports Medicine – Open*, 10(1), article number 10. doi: 10.1186/s40798-024-00677-w.
[28] Saul, D., Steinmetz, G., Lehmann, W., & Schilling, A.F. (2019). Determinants for success in climbing: A systematic review. *Journal of Exercise Science & Fitness*, 17(3), 91-100. doi: 10.1016/j.jesf.2019.04.002.
[29] Skriver, S.A., Sørensen, R., Oxfeldt, M., & Dalgas, U. (2024). Muscle strength in sport climbing: A systematic review and meta-analysis. *The Journal of Sports Medicine and Physical Fitness*, 65(1), 80-89. doi: 10.23736/S0022-4707.24.15925-7.
[30] Stanković, D., Pavlović, V., & Petković, E. (2019). The influence of coordination on the results in sports climbing: The underlying relations. In *XXII international scientific conference "FIS communications 2019" in physical education, sport and recreation* (pp. 21-26). Niš: University of Niš.
[31] Sterkowicz, S., Jaworski, J., & Rokowski, R. (2014). Importance of coordination motor abilities in expert-level on-sight sport climbing. *Medicina Sportiva*, 18(1), 16-23. doi: 10.5604/17342260.1094782.
[32] Stien, N., Riiser, A., Shaw, M.P., Saeterbakken, A.H., & Andersen, V. (2023). Effects of climbing- and resistance-training on climbing-specific performance: A systematic review and meta-analysis. *Biology of Sport*, 40(1), 179-191. doi: 10.5114/biolsport.2023.113295.
[33] Taylor, N., Giles, D., Panáčková, M., Mitchell, J., Chidley, J.B., & Draper, N. (2020). Climbing performance analysis: A novel tool for the assessment of rock climber's movement performance. *International Journal of Sports Physiology and Performance*.
[34] Turchetto, M., Tomaselli, V., Giorgi, F., Leone, S., & Leo, I. (2025). Sport climbing competence is influenced by training frequency, experience, self-efficacy, flow, and emotional intelligence. *Frontiers in Psychology*, 16, article number 1518495. doi: 10.3389/fpsyg.2025.1518495.
[35] Vasile, A.I., Stanescu, M., & Pelin, F. (2021). Features of tactical and psychological training models in sports climbing at youth level. *Journal of Educational Sciences & Psychology*, 11(73(1)), 153-162. doi: 10.51865/JESP.2021.1.14.
[36] Zhang, H., Wen, Y., Bu, H., Zhu, H., Han, M., & Liu, J. (2026). Kinematic determinants of the Tomoa skip starting in elite male speed climbing athletes. *Sports Biomechanics*. doi: 10.1080/14763141.2026.2649469.

Особливості етапу початкової підготовки спортсменів у спортивному скелелазінні

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Анотація. Мета дослідження полягала в теоретичному обґрунтуванні особливостей фізичної та технічної підготовки спортсменів на початковому етапі тренувального процесу у спортивному скелелазінні. Дослідження виконано в межах теоретико-методичного підходу із застосуванням теоретичного аналізу наукових джерел та логіко-структурного моделювання. Результати дослідження засвідчили, що підготовка спортсменів-початківців має комплексний характер і базується на інтеграції фізичних якостей та технічних умінь, серед яких визначальними постає сила хвата, координаційні здібності та витривалість. Встановлено, що сила хвата забезпечує можливість утримання положень і виконання переходів, а її розвиток потребує поступовості та врахування індивідуальних можливостей спортсменів. Визначено, що координаційні здібності виконують системоутворюючу функцію, оскільки саме вони забезпечують ефективність засвоєння технічних елементів, точність рухів і адаптацію до умов траси. Узагальнення наукових джерел дозволило визначити ефективні засоби підготовки, зокрема вправи на висах і утриманнях, лазіння по простих трасах, балансувальні та координаційні вправи, а також тривалі й інтервальні навантаження адаптивного характеру. Обґрунтовано, що ефективність підготовки має забезпечуватися інтегрованим використанням зазначених засобів, варіативністю умов виконання та поступовим ускладненням рухових завдань. Розроблена структурно-логічна модель відобразила взаємозв'язок між фізичними якостями та технічною підготовкою, визначила пріоритетність розвитку координаційних здібностей і передбачала поетапне формування рухових дій. Встановлено, що раціональне дозування навантаження сприятиме безпечному розвитку спортсменів і запобіганню перевантаження. Практичне значення дослідження полягає у можливості застосування його результатів тренерами зі спортивного скелелазіння, викладачами фізичної культури та фахівцями дитячо-юнацьких спортивних шкіл для оптимізації тренувального процесу та забезпечення безпечного розвитку фізичних і технічних якостей

Ключові слова: фізичні якості; сила хвата; витривалість; тренувальний процес; ефективність засвоєння технічних дій

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 15.12.2025.Revised: 14.04.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.92.093
DOI: 10.69587/tppcs/1.2026.47

Ski mountaineering as a new Olympic sport: Development trends and training requirements for athletes

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Abstract. The aim of the study was to identify the characteristic features of the organisation of training for ski mountaineering athletes, based on trends in its development in the context of its attainment of Olympic status. The research methodology was based on the use of historical-logical, analytical-synthetic, structural-functional and generalising-comparative methods, which ensured a comprehensive analysis of the evolution of ski mountaineering, current trends in its development and the specifics of training athletes in mountain conditions. It was found that ski mountaineering has evolved from a practical means of movement in mountainous conditions into a structured international sport combining mountaineering techniques, ski training and high demands on physical endurance. Its institutionalisation through international federations, the standardisation of competitions and its inclusion in the Olympic programme reflect the transition to a modern, high-tech discipline integrated into the global sporting system. It was noted that the contemporary development of ski mountaineering is characterised by a rapid rise in popularity, a shift towards short, highly dynamic competition formats, and a significant increase in the intensity of physical exertion. At the same time, equipment is becoming more technologically advanced and the training process is intensifying, which, together with its inclusion in the Olympic programme, is transforming the sport into a media-friendly and highly specialised discipline. Its inclusion in the Olympic programme and the reduction in the duration of competition formats by 90-95% reflect its transformation into a high-speed and technology-oriented discipline with an emphasis on media appeal and efficiency. It was found that the training system combines endurance, strength, coordination and technical skills, ensuring the comprehensive adaptation of athletes to challenging mountain conditions and variable loads. The practical significance of this work lies in the possibility of using the results obtained to improve the training system for athletes in ski mountaineering and other mountain endurance sports, thereby enhancing their physical performance, technical efficiency and adaptation to challenging environmental conditions

Keywords: aerobic endurance; mountain conditions; biomechanics of movement; physiological stress; training

Introduction

Ski mountaineering, as a new discipline in the Olympic programme, is attracting increasing attention due to its combination of high physical demands, technical skill and specific requirements for athletes' functional readiness. The inclusion of this discipline in the Olympic Games programme has heightened interest in studying trends in its development, training systems and factors influencing performance outcomes. Studying the specifics of training for ski mountaineering helps to improve the training process, enhance athletes' competitiveness and broaden scientific understanding of the development of new Olympic disciplines.

The growing scientific interest in ski mountaineering is linked to its inclusion in the Olympic programme and the need for a deeper understanding of the factors influencing sporting performance. V.R. Schöffl *et al.* (2023) conducted a narrative review of the scientific literature on ski mountaineering as a new Olympic discipline. The authors summarised data from regarding physiological loads, typical injuries and the specifics of athletes' competitive activities. Increasing demands on sporting performance are driving a focus on the technical aspects of training. L. Bortolan *et al.* (2023) analysed the development of ski mountaineering equipment. The researchers described changes in the design of skis, bindings and boots that help to reduce the weight of the equipment and improve movement efficiency. Performance in winter disciplines also depends on the

Suggested Citation: Trachuk, I. (2026). Ski mountaineering as a new Olympic sport: Development trends and training requirements for athletes. *Theory and Practice of Physical Culture and Sports*, 5(1), 47-57. doi: 10.69587/tppcs/1.2026.47.

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gliding properties of the equipment and its interaction with the snow surface. A. Almqvist *et al.* (2025) examined the influence of friction on performance in Winter Olympic sports. Optimising surfaces and selecting materials can improve athletes' speed and efficiency.

The development of skiing has been accompanied by an expansion of the scientific base, which lays the groundwork for new research in ski mountaineering. W. Hou *et al.* (2024) conducted a bibliometric analysis of global research on skiing from 1974 to 2023. They identified an increase in the number of publications, key thematic areas and a rise in interdisciplinary approaches. The spread of ski mountaineering is linked not only to high-performance sport but also to changes in recreational culture. M. Nevicato *et al.* (2025) investigated the transformation of ski touring at the turn of the 20th and 21st centuries. The researchers demonstrated that this activity is becoming multifunctional, combining sporting, tourist and health-related motivations for participation. The expansion of winter activities is also influencing the tourism sector in mountain regions. A. Bortolotti *et al.* (2024) examined sport as a practice of well-being through the integration of sport, wellness and health. It is noted that sporting events and mountain disciplines contribute to the diversification of tourism services and regional development. The training of athletes also depends on the broader socio-economic conditions governing the recreational sector. D.S. Kan (2024) analysed the historical conditions of the formation of Ukraine's tourism and recreation sector and its development in the era of sustainable multimodal mobility. The author outlined the factors of infrastructure modernisation that may influence the accessibility of mountain activities and sporting practices. The historical preconditions for the development of recreation in Ukraine are highlighted in collective studies. V. Tsypko *et al.* (2024) investigated the formation of Ukraine's tourism and recreation sector and the directions of its further development, emphasising the role of transport mobility, investment and regional potential for active tourism. The spread of ski culture is increasingly linked to digital communications and the media environment. C. Zhao & H. Shen (2024) investigated the moderating effect of ski influencers on intentions to participate in ski tourism. It was found that the influence of online opinion leaders enhances interest in winter activities and fosters motivation to participate.

Despite the aspects highlighted by the aforementioned authors, the gaps included a lack of attention to athletes' long-term adaptive mechanisms in variable mountain conditions and their impact on the consistency of results. Furthermore, the integration of psychological preparation with the physiological and technical components of the training process is only briefly addressed. Additionally, the system for comprehensively assessing the effectiveness of training in high-altitude conditions, taking into account the specific nature of competitive ski mountaineering, requires further in-depth study. The aim of the study was to identify the characteristics of training for ski mountaineering athletes, taking into account current trends in the development of this sport and its inclusion in the Olympic programme. The objectives of the study were to identify the key stages in the development of ski mountaineering, assess current trends in its development, and determine the specific nature of training for athletes in mountain conditions.

Materials and Methods

The research methodology was based on the use of four interrelated theoretical methods, namely the historical-logical, analytical-synthetic, structural-functional and generalising-comparative approaches, which enabled a comprehensive analysis of the historical development of ski mountaineering as an Olympic discipline, current trends in its development and the specific nature of athlete training. In the first stage, a historical-logical method was employed, which made it possible to trace the evolution of ski mountaineering from a practical means of locomotion in mountainous terrain to an officially recognised sporting discipline. Within the framework of this method, an analysis was carried out of the process of its inclusion in the international sporting calendar and, in particular, in the Olympic programme. This made it possible to identify the key stages in the institutionalisation of the sport, the factors that influenced its Olympic recognition, and the role of international sports federations in standardising competition rules. The source base consisted of regulatory materials from the International Ski Mountaineering Federation (2026) and the Encyclopaedia Britannica (n.d.). Information resources from Dynafit (2025) and Tribuna (n.d.), which covered the development and current state of ski mountaineering, were also examined. Additionally, the international regulations of the ISMF World Cup (International Ski Mountaineering Federation, 2023) and analytical materials from the International Testing Agency (n.d.) were examined, which pertain to the organisational and regulatory aspects of the sport's development in the context of its Olympic integration. Statistical data was collected through a systematic review of the aforementioned open international sources. The data obtained was structured according to key indicators of the development of ski mountaineering, including competitive activity, regional participation and the characteristics of training processes.

In the second stage, an analytical-synthetic method was applied, which was used to identify the main trends in the development of ski mountaineering based on an analysis of international academic sources and industry reports, in particular the works of L. Bortolan *et al.* (2021) and M. Tarabini *et al.* (2026), which reflect changes in the competitive structure, physiological loads and regional organisation of the global ski industry, specifically in regions such as Europe, North America, the Asia-Pacific region, South America, the Middle East and Africa.

In the third stage, a structural-functional approach was applied, which made it possible to view ski mountaineering as a holistic system of interrelated components of sporting activity and to incorporate the main types of training methods. The study analysed the structure of training in ski mountaineering as a system of interrelated physical, functional and technical-coordination components, including aerobic endurance, strength training, high-intensity interval training and specific skills for transitional movements. A separate stage was devoted to the analysis of sports equipment, within which the technical parameters of the gear were assessed in terms of their impact on movement efficiency, safety and competitive performance. The

theoretical framework was based on data from the International Ski Mountaineering Federation (2026) and a synthesis of methodological approaches from Peak Experience (n.d.), reflecting current requirements for physiological training, energy supply and technical efficiency in mountain endurance sports. In the final stage, a generalising and comparative method was applied, through which the requirements for the training of athletes in ski mountaineering were presented.

Results

An overview of the evolution of ski mountaineering from a practical form of mountain travel to a modern Olympic sport

Ski mountaineering (skimo) is a demanding form of alpine skiing that combines elements of mountaineering, ski touring and cross-country skiing in mountainous terrain. Its origins lie not in sporting practice, but in the practical necessity of getting around in the high-altitude regions of the Alps, the Pyrenees and other mountain ranges in Europe. In the 19th and early 20th centuries, skis were used as a means of transport in snow-covered mountains by the military, rescue teams and the local population. It was this practical function that laid the foundations for the future sporting discipline, as the technique of moving on skis in the mountains gradually began to incorporate elements of competition between mountaineers and mountain guides. The evolution of ski mountaineering as a sport began with the organisation of the first informal competitions in the mid-20th century, when time trials involving ascents and descents along mountain routes began to be held in the Alps. In the 1970s and 1980s, rules were gradually established, routes were standardised, and the first sports clubs specialising specifically in skimo emerged. A key milestone was the creation of international bodies that began to coordinate the development of the sport across various countries, including France, Italy, Switzerland, Austria and Spain (Tribuna, n.d.).

The International Ski Mountaineering Federation, which was officially established in 2008, played a significant role in the transformation of ski mountaineering. It was the International Ski Mountaineering Federation that ensured the standardisation of competition rules, the systematisation of disciplines (individual races, sprints, relays, team races), and the integration of the sport into the international calendar (International Testing Agency, n.d.). For example, world championships and World Cup stages have become regular events, which has contributed to raising the level of professionalism among athletes and coaches. Ski mountaineering differs from its historical precursors and military-practical mountain movement, which combined ascents and descents on skis without clear sporting regulations. Whereas in the early days of ski mountaineering the main objective was to overcome natural obstacles in the mountains, by 2025-2026 it will be a highly structured sport with regulated distances, standardised equipment and a dedicated sporting infrastructure. Competitions involve alternating between ascents on skis using special bindings, carrying skis over difficult sections, and technical descents at high speed. This creates a physical exertion profile that combines endurance, speed and strength, and technical skill.

A distinctive feature of the development of ski mountaineering is its rapid integration into the Olympic sports programme. Following many years of development at the level of international federations, in 2021 the International Olympic Committee decided to include ski mountaineering in the programme of the 2026 Winter Olympic Games in Milan-Cortina (International Olympic Committee, 2021). This marked a stage in the sport's institutionalisation, as it moved from the category of extreme and niche disciplines to official Olympic status. The Olympic programme includes the short and dynamic disciplines of sprint and mixed relay, reflecting the general trend in modern sport towards shortening the duration of competitions and increasing their spectacle value. An example of the level of development in ski mountaineering is the ISMF World Cup stages, where athletes tackle routes with an elevation gain of up to 1,500 metres, demonstrating an average ascent speed of over 1,500 vertical metres per hour. Such figures indicate extremely high demands on athletes' functional fitness, particularly regarding maximum oxygen uptake (VO_2 max), the efficiency of aerobic energy supply, and the ability to perform under hypoxic conditions (Dynafit, 2025).

Another aspect of this evolution is the increasing use of technology in equipment. Modern skimo skis are lighter than those of previous decades (the 1980s to 2000s), which helps to reduce energy expenditure during ascents. Carbon materials, lightweight boots and adaptive bindings are also widely used, enhancing movement efficiency. This demonstrates the sport's transition to a high-tech level, where results depend not only on physical fitness but also on innovations in sports equipment. Table 1 shows the evolution of ski mountaineering from practical mountain travel to an internationally recognised sporting discipline, which has gone through the stages of establishing competitions and inclusion in the Olympic programme.

Table 1. The evolution of ski mountaineering from practical mountain travel to an Olympic discipline

Period / Stage	Characteristics of development	Key features
Ancient practices (before the 19th century)	Use of skis as a means of transport in mountainous and snow-covered regions	Practical function: transport, hunting, military needs; absence of a sporting element
19th – early 20th centuries	The development of downhill skiing and mountaineering techniques in Europe	Combining ascents and descents in the mountains; first expeditions and sporting attempts to conquer routes
1910s-1950s	Military and expeditionary use of skis in the mountains	Active use in military units; development of techniques for moving in difficult conditions
1960s-1980s	The emergence of the first informal competitions	The emergence of mountain races; the development of backcountry skiing and ski touring as precursors to the sport

Table 1, Continued

Period / Stage	Characteristics of development	Key features
1990s-2007	Institutionalisation of the sport	Establishment of international organisations (ISMC, later ISMF); the first official world championships; standardisation of rules
2008-2015	Establishment of the international sporting system	Regular World Cups; expansion of disciplines (sprint, individual races, relays); increased professionalisation
2016-2020	Recognition by the IOC and inclusion in the Youth Olympic Games	Official recognition by the International Olympic Committee; inclusion in the Youth Olympic Games
2021-2026	Olympic integration	Inclusion in the programme of the 2026 Winter Olympic Games (Milan-Cortina); debut in the sprint and mixed relay formats

Note: IOC – International Olympic Committee; ISMC – International Ski Mountaineering Committee; ISMF – International Ski Mountaineering Federation
Source: compiled by the author based on research from Encyclopaedia Britannica (n.d.)

In practice, the evolution of ski mountaineering has been marked by a shift from the utilitarian use of skis in mountainous and military contexts to an organised sporting activity with clear rules and standardised routes. Initially, skiing in high-altitude regions served the purposes of transport, hunting and supporting military operations in challenging terrain. Subsequently, informal mountain races emerged, in which the key criterion was the speed of ascending and descending slopes in natural conditions. As the sport developed further, international competitions were established, and specialised equipment, training systems and methods emerged, aimed at developing endurance, speed and strength, and technical skill. In its modern form, ski mountaineering functions as a highly dynamic sport that combines intense physical exertion with challenging mountain routes and requires comprehensive physical and tactical preparation of athletes. Ski mountaineering has undergone a complex evolution, transforming from a practical means of getting around in the mountains into an internationally recognised sporting discipline and an Olympic sport. Its development has been characterised by gradual institutionalisation, the standardisation of rules, the growth of sporting competition, and integration into the global Olympic system. This allows ski mountaineering to be regarded as one of the most dynamic winter sports, combining the traditions of mountain culture with the high demands of professional sport.

Trends in the contemporary development of ski mountaineering

The development of ski mountaineering (skimo) is characterised by a range of interrelated trends, encompassing social and promotional, competitive and organisational, physiological and technological aspects. Overall, between 2000 and 2025, the sport has seen a steady increase in popularity of approximately 60-80% globally, linked to its transition from a niche mountaineering practice to an organised international sporting discipline and its inclusion in the programme of the 2026 Olympic Games (Encyclopaedia Britannica, n.d.). This has increased media attention, commercialisation and the involvement of new countries, particularly outside the traditional Alpine regions.

One of the key trends in the development of ski mountaineering is a significant shift in the structure of competitive demands, characterised by shorter distances and increased intensity. Whereas classic disciplines involved individual races lasting 60-180 minutes with significant elevation gains of up to 2,000-2,400 m, the modern Olympic format is predominantly focused on the sprint (≈3 minutes) and the mixed relay (≈7 minutes per participant) (Tarabini *et al*., 2026), which generally means a reduction in the duration of the competitive workload by approximately 90-95%. At the same time, this transformation does not imply a reduction in endurance requirements, as competitions take place in a format of repeated explosive efforts with short recovery phases, significant elevation changes and high intensity density throughout the entire competition day or series of races. This is precisely why training must continue to focus on developing both a strong aerobic base and the ability to maintain intensity under conditions of accumulated fatigue.

Another trend is the increasing use of technology in sports equipment. The weight of a complete set (skis, boots, bindings) has been reduced by an average of 20-30%, which has had a direct impact on climbing speed, as it has been proven that every kilogram of weight reduction in equipment increases climbing efficiency by 2-4%. Modern sprint skis are around 150-160 cm long, made from carbon composites and optimised for rapid changes in skiing style. "Skins" (anti-slip pads) have also been significantly improved, increasing the grip coefficient to 85-90% without losing gliding speed. Technological progress also extends to binding and boot systems: modern models allow the transition time between movement modes to be reduced to 3-5 seconds, which is critical in sprint races. In addition, digital analysis systems, GPS tracking (Global Positioning System tracking) and power sensors are being actively introduced, allowing for real-time monitoring of load and improving the efficiency of the training process (Bortolan *et al*., 2021).

The level of development of ski mountaineering and the related ski industry varies from country to country, due to historical traditions, natural and geographical conditions, levels of investment, infrastructure and state support for sport. Consequently, this results in varying rates of growth and differing levels of technological and sporting "maturity" across countries. Countries in the Alpine region (France, Italy, Switzerland, Austria) have the highest level of development and the most stable rates of progress, which is explained by the historical foundation of mountain sports and the established infrastructure. Table 2 reflects the regional structure of the global ski industry, demonstrating the dominance of Europe and North America, with a gradual increase in the share of the Asia-Pacific region and a smaller presence of other regions of the world (South America, the Middle East and Africa).

Table 2. Regional characteristics of the development of ski mountaineering

Region	Characteristics of development (with specific features)
Europe	Europe is the heart of ski mountaineering: every year, over 60-70% of the ISMF World Cup and Continental Cup stages are held here. National teams operate in France, Italy, Switzerland, Spain and Austria, which regularly take part in the ISMF World Championships. The region has an extensive network of specialist skimo clubs and high-altitude training bases in the Alps. It is here that the bulk of the Olympic qualification process for Milano-Cortina 2026 takes place.
North America	The region is represented by the United States and Canada, where national federations and national teams operate and regularly take part in ISMF World Championships and World Cup events (accounting for approximately 10-15% of starts). Skimo clubs are active (for example, in Colorado and British Columbia), and training programmes are integrated with mountaineering and alpine skiing programmes. There are well-established commercial skimo events and competition series.
Asia-Pacific region	Development is concentrated in Japan, China and South Korea, where national skimo teams have been established to participate in ISMF events and qualify for the 2026 Olympic Games. In Japan (Hokkaido), there are specialised clubs and university training programmes. China is actively investing in the development of mountain training centres following the 2022 Winter Olympics. The proportion of international events is gradually increasing (5-10%).
South America	The sport is concentrated in Chile and Argentina, where there are local ski mountaineering clubs and national federation teams that regularly compete in the ISMF Continental Cup (typically 2-5 international events per season). The main centres are in the Andes (Bariloche, La Parva). Training facilities are seasonal and dependent on weather conditions.
The Middle East and Africa	The region is in the early stages of development: participation in ISMF competitions is sporadic or represented by individual athletes without fully-fledged national teams. In the UAE, Turkey and Morocco, the first initiatives for skimo clubs and training programmes based at artificial ski resorts are taking shape. There is no systematic participation in the Olympic qualification cycle.

Source: compiled by the author based on research by the International Ski Mountaineering Federation (2023)

The analysis carried out has shown that the development of ski mountaineering is characterised by regional differences, which are determined by varying levels of infrastructure provision, financial resources, climatic and geographical conditions, and the degree to which this sport is integrated into the national sports policy framework. The main difference between regional trends lies in the stage of development and the functional role of ski mountaineering: ranging from a highly developed and institutionalised sports system in some regions to the initial formation and experimental implementation in others. This indicates the uneven global development of the sport and determines different strategic approaches to its further popularisation, professionalisation and integration into the international Olympic movement.

A systematic approach to training in ski mountaineering

Ski mountaineering is regarded as a holistic system of interrelated components of sporting activity, as success in this discipline is determined not by individual physical attributes, but by the integration of endurance, strength, technique, coordination and the ability to function effectively in the changing mountain environment. Within this system, the training process incorporates complementary methods, such as prolonged steady-state aerobic exercise to build basic endurance, interval mountain climbs to develop the anaerobic threshold, back-to-back training to simulate accumulated fatigue, technical transition exercises to automate transitions between movement phases, as well as training under conditions of limited recovery to prepare for real-world mountain situations (Alpenglow Expeditions, n.d.). Their combination ensures not the isolated development of individual qualities, but the formation of a comprehensive adaptation of the body to prolonged exertion, where each element of training influences the effectiveness of another, creating a unified functional model of the athlete's preparedness for the specific demands of mountain routes.

In ski mountaineering and related mountain endurance sports, quite specific training methods are used, which are directly linked to the actual conditions of moving through the mountains. One of the basic methods is steady-state endurance, where the athlete works in a stable aerobic mode for 60-180 minutes without sudden changes in intensity. This builds "long-distance endurance", which allows the athlete to maintain a consistent pace during ascents lasting several hours. In practice, this might involve a continuous uphill climb with a rucksack or prolonged cyclic exercise (running/cycling) in the moderate heart rate zone, simulating real mountain conditions (Johnston, 2024).

The second most popular method is hill interval training, which involves alternating short bursts of high-intensity effort with recovery phases. The aim is to develop the ability to perform under conditions of a sudden increase in workload, such as when tackling a steep slope or navigating challenging terrain. In practice, this is achieved through a series of 3-6-minute climbs at a high pace with a short rest during the descent or walking (RMI Expeditions, n.d.). This approach raises the anaerobic threshold and improves tolerance to muscle acidification, which is particularly important during competitions or fast climbs. The back-to-back training method is also widely used, which involves two consecutive days of prolonged exertion. It simulates multi-day mountain routes, where fatigue builds up gradually and does not have time to be fully recovered. For example, the first day might involve 3-4 hours of climbing, whilst the second consists of a shorter but technically demanding session. This builds the ability to perform under conditions of chronic fatigue and maintain proper technique even when energy reserves are depleted.

A particular focus is placed on transition training, which aims to automate changes in specialised equipment and movement patterns. It involves repeatedly practising actions involving climbing skins, bindings, skis and a rucksack at the fastest possible pace. For example, an athlete repeatedly goes through the cycle of "removing boots – securing equipment – starting the descent", minimising the transition time. This is critically important in competitive sport, where every second affects the result. Another modern method is fatigue training, where technical or strength

exercises are performed after prolonged exertion (New South Wales Institute of Sport, 2022). This allows for the simulation of situations where the athlete is forced to make decisions and maintain technique whilst already fatigued. Taken together, all these methods develop not only physical fitness but also the ability to function effectively in real mountain conditions, where the workload is unpredictable and multifaceted. Table 3 summarises the structure of training in ski mountaineering as a system of interrelated physical and technical components, including endurance, strength, coordination and transitional skills, aimed at developing the athlete's overall performance in mountain conditions.

Table 3. The structure of athletic training in ski mountaineering as a system comprising physical, speed-strength and technical-coordination components

Training component	Type of exercise	Recommended volume / Frequency	Training methods	Key adaptation	Training objective
Aerobic endurance	Low-moderate intensity (60-80% HRmax)	2-4 times a week, 60-120 mins	Running, cycling, stairs, long climbs	Increasing VO_2max, optimising movement	Building basic endurance for long climbs
Intense climbs	High intensity (85-95% HRmax)	Once a week	Interval climbs, hill running, treadmill uphill	Development of anaerobic threshold and power	Ability to tackle steep sections and maintain a variable pace
Strength training	Strength / functional	Twice a week	Squats, lunges, step-ups, core training	Core stability, lower body strength	Improving running efficiency under load
Speed and strength training	Explosive strength	1-2 times a week	Plyometrics, jumping exercises, short sprints	Development of explosive power	Improving speed at the start and on difficult sections
Eccentric strength (descents)	Strength endurance	1-2 times a week	Controlled descents, step-downs, slow lunges	Resistance to eccentric loads	Control of muscle fatigue during descents
Lifting technique	Coordination and technique	1-3 times a week (during the season)	Moving along the ascent track, working with skis	Economy of movement, rhythm	Automation of climbing technique
Downhill technique	Coordination and strength	1-2 times a week	Descents in various snow conditions	Balance, speed control	Improving safety and efficiency on the slopes
Transition skills	Speed and coordination	2-3 times a week	Switching modes, working with bindings	Speed of transitions	Minimising time loss between movement phases
Long training sessions	General endurance	Once a week	2-5 hours of continuous activity (climbing/descending)	Psychophysical endurance	Simulation of competitive activity
Back-to-back sessions	Accumulated fatigue	1 cycle every 1-2 weeks	Two consecutive days of intense training	Training whilst fatigued	Preparation for multi-day races
Mobility	Recovery	10-15 mins after training	Stretching joints and muscles	Maintaining range of motion	Optimisation of technique and injury prevention
Working with equipment	Specific speed and strength	During training	Skis, boots, bindings, rucksack 3-8 kg	Adapting to extra weight	Stability and efficiency in competitive conditions

Source: compiled by the author based on research by Peak Experience (n.d.), International Ski Mountaineering Federation (2026)

The types of training loads listed above reflect a multi-level training system in ski mountaineering, designed to develop specialised fitness for high-altitude conditions. Aerobic endurance provides the basic capacity for prolonged moderate-intensity work, interval and strength training build resilience to high physical exertion and raise the anaerobic threshold, whilst technical training and transition skills optimise movement efficiency and reduce time lost during competitions. Long training sessions simulate competition conditions, whilst mobility and equipment handling ensure technical consistency and biomechanical efficiency, together forming an integrated system of physical, coordination and technical training for the athlete. Table 4 summarises the comparative characteristics of training for athletes in ski mountaineering and related mountain endurance sports, revealing its comprehensive and multi-component nature, which combines physical, technical and tactical requirements, in contrast to the more narrowly specialised training models in mountain running and cycling.

Table 4. Specific features of training in ski mountaineering compared with mountain endurance sports

Comparison criterion	Ski mountaineering	Mountain running / Trail running	Mountain cycling
Primary physical quality	A combination of aerobic endurance with speed-strength and coordination components	Predominance of aerobic endurance and lower-body muscular endurance	Aerobic endurance with an emphasis on strength endurance of the lower limbs
Biomechanics of movement	Gliding cyclic movement using skis and poles, changing modes of movement (ascent, descent, transitions)	Running movement with constant impact load on the musculoskeletal system	Cyclic pedalling with minimal impact load

Table 4, Continued

Comparison criterion	Ski mountaineering	Mountain running / Trail running	Mountain cycling
Muscle load	Comprehensive engagement of the lower and upper limbs, high levels of coordination	Predominant load on the lower limbs with pronounced eccentric work	Predominant load on the lower limbs (quadriceps, calf muscles)
Technical difficulty	High, related to the use of equipment, changes in movement patterns and locomotion	Moderate, related to running technique on challenging terrain	Moderate, related to cycling in mountainous conditions
Tactical requirements	High, including assessment of snow conditions, route selection and pace	Moderate, related to pacing and effort management	Moderate, related to route selection and pace
Environmental factors	Significant influence of snow conditions, weather and altitude	Influence of terrain, temperature and altitude	Impact of terrain and road surface
Training considerations	Integration of endurance, technique, equipment handling and coordination skills	Focus on developing endurance and running technique	Focus on developing strength endurance and pedalling technique

Source: compiled by the author based on research by V. Menz *et al.* (2021), M. Lasshofer *et al.* (2023)

The results obtained indicate that the training of athletes in ski mountaineering should be structured as an integrated system of training stimuli, in which the development of aerobic endurance is combined with the improvement of technical skills in handling equipment, coordination abilities and speed-strength qualities. A comparative analysis of training systems for athletes in ski mountaineering and related endurance sports has revealed a fundamental difference in the structure of the training process and the logic behind the development of competitive readiness. It was established that ski mountaineering is characterised by an integrated training model, combining aerobic endurance, speed-strength components, coordination skills and equipment handling technique, whereas in mountain running and cycling there is a more unidirectional focus on the development of individual energy systems. This revealed that performance in ski mountaineering is determined not only by the level of endurance, but also by the ability to rapidly change movement patterns and adapt to complex mountainous terrain.

An analysis of the impact of the International Testing Agency's (n.d.) regulatory requirements revealed that the anti-doping system establishes standardised conditions for training and competition, influencing the structure of training loads, medical and biological support, and the monitoring of athletes' recovery. It has been established that compliance with international anti-doping standards not only ensures the integrity of competitions but also indirectly influences training methodologies, increasing the importance of long-term load planning and monitoring of athletes' functional status. Furthermore, a comparative analysis of the role of international federations, in particular the International Ski Mountaineering Federation (2026), revealed that the standardisation of courses, the regulation of elevation changes, technical sections and transition zones, as well as unified judging rules, directly shape the specifics of the training process. It was established that it is precisely these regulatory requirements that determine the structure of competitive activity, influence the design of training programmes and ensure the comparability of results at the international level, making the regulatory system a key factor in the development of the sport.

Discussion

The inclusion of ski mountaineering in the Olympic programme reflects a global trend towards combining sport with active tourism. This is consistent with the findings of N. Batyrbekov *et al.* (2024), in which the authors examined the development of sports tourism in Kazakhstan and emphasised that mountain activities help to promote physical activity among young people. The study highlights that the natural environment and adventure sports are becoming an important tool for fostering a culture of health, which directly aligns with the concept of ski mountaineering. This correlates with M. Cheng *et al.* (2023), where, in particular, the researchers analysed the coordinated development of sport and tourism and identified the factors stimulating economic and social growth in these sectors. New disciplines associated with natural locations have high potential for international promotion and audience engagement, which aligns with R.V. Ciomag & C. Pop (2024), who examined the cultural and sporting characteristics of nations participating in international competitions and demonstrated their impact on results and sporting representation. These findings explain why countries with established mountaineering traditions have better conditions for the successful development of ski mountaineering. The integration of ski mountaineering into the Olympic movement requires an update to approaches to athlete training. This is confirmed by E. Ellmer *et al.* (2024), who described current megatrends in sport and their impact on the process of athlete training and the preparation of coaching staff. The study notes that innovative sports require flexible methodologies, individualisation and interdisciplinary knowledge, which is particularly relevant to ski mountaineering.

Hosting the Olympic Games stimulates the development of infrastructure that can be used to promote ski mountaineering, which is consistent with G. Fossa et al. (2025). The researchers examined the creation of a sports and cultural corridor for the Olympics in Valtellina and demonstrated the importance of combining heritage, spatial planning and sports facilities. Olympic projects can leave a long-term legacy for the training and competitive use of new disciplines. Modern training for ski mountaineering athletes is impossible without digital technologies and effective resource management, as noted in B. Gao *et al.* (2025). The digitalisation of the allocation of sports resources in winter sports has been analysed, and its impact on improving the efficiency of the training process has been demonstrated. These approaches can be applied to training planning, the use of trails, and the monitoring of ski mountaineers' fitness. Training in ski mountaineering

places high demands on the functional state of the cardiovascular system and the ability to recover. This was confirmed by J.S. Gąsior *et al.* (2024), who investigated heart rate dynamics and the asymmetry of regulatory processes in ski mountaineers during stimulation of sympathetic activity and recovery. The results demonstrated the importance of monitoring the body's autonomic responses to optimise training loads and prevent overexertion. This is consistent with the findings of Y. Jiang *et al.* (2023), who established that observing major events on social media strengthens the intentions of the younger generation to participate in sports tourism. This pattern suggests that the Olympic debut of ski mountaineering could become a powerful factor in attracting young people to the sport.

The role of dopamine, as well as genetic and epigenetic factors, in the development of personality and sporting performance has been analysed, in line with L. Li (2023). The challenges and avenues for the development of ecosports tourism in the post-pandemic period have been examined, and attention has been drawn to the need for the balanced use of natural resources. This approach is particularly important for ski mountaineering, as its competitions and training depend directly on the state of the mountain environment. This is consistent with the provisions set out in the work of R. Melo *et al.* (2023), where nature-oriented sports are viewed as combining physical activity and interaction with the natural environment. Training for ski mountaineering athletes is characterised by a high reliance on the development of aerobic endurance, speed-strength qualities, and the ability to recover quickly after prolonged ascents and descents. These observations are consistent with the findings of E. Tønnessen *et al.* (2024), who described a model of training sessions in endurance sports as being based on alternating loads of varying intensity and a significant proportion of specific training on terrain similar to that of competition.

The technical complexity of ski mountaineering requires constant refinement of skills in traversing slopes of varying gradients, rapid transitions between modes of movement, and the use of specialised equipment. These findings align with the historical analysis by I. Lidström (2025), in which the evolution of skiing in Sweden was viewed as a process of continuous technological adaptation of equipment and movement techniques to natural conditions. This allows ski mountaineering to be interpreted as a continuation of a long-standing line of development in skiing disciplines, in which technical progress is closely linked to the functional needs of athletes. These observations are consistent with the findings of G. Si *et al.* (2025), where an analysis of the psychological support provided to Olympic teams shows that anxiety regulation, concentration and resilience to psycho-emotional stress play an important role in athletes' performance. The development of ski mountaineering as a discipline is closely linked to the infrastructure of mountain regions. The data obtained are consistent with the views of R. Leber (2024), who describes winter sports tourism as a sector that combines economic and environmental aspects of regional development. This allows ski mountaineering to be interpreted not only as a sporting discipline, but also as a factor in shaping tourist flows and the development of mountain regions.

Digitalisation and technological innovation are beginning to influence the training process for athletes in endurance sports. In particular, the use of artificial intelligence models to analyse training loads and recovery is described in the work by Z. Miao & G. Ge (2023), which notes a trend towards the introduction of digital systems for monitoring athletes' physiological condition into the training process for ski mountaineering. This view is supported by L. Nima (2023), who considers social groups and sporting communities as factors influencing motivation and the regularity of the training process. In the case of ski mountaineering, group interaction during training in mountainous conditions fosters trust and mutual support among athletes. associated with challenging terrain and high-intensity exertion. In their work, C. Rotllan & G. Viscor (2023) noted that among elite female athletes in winter sports, there is an elevated incidence of lower limb injuries and overuse injuries. The technical specifics of the discipline create similar risk mechanisms. A separate section of the analysis concerns trends in the development of sport in the digital age. In their work, L. Zhipeng *et al.* (2025) demonstrated that sports tourism and sporting disciplines are increasingly being studied through the lens of digital data and international comparisons. There is a growing interest in the use of digital platforms for training planning and route analysis in ski mountaineering. In the study by L. Zhouxiang (2024), it was highlighted that VR (Virtual Reality) technologies are used to simulate sporting situations and practise tactical decisions. The results show that such approaches can be applied to the training of ski mountaineers, particularly for practising reactions in challenging weather conditions and on hazardous sections of the route. Thus, the current development of ski mountaineering is characterised by the active integration of digital technologies into the training process, which enhances the effectiveness of load management, recovery and tactical simulation.

Conclusions

Ski mountaineering has undergone a multi-stage evolution from a utilitarian means of transport in mountainous terrain to a modern Olympic sport that combines mountaineering techniques, skiing and high demands on physical endurance. Its development has spanned stages ranging from the military and practical use of skis in the 19th and 20th centuries to the emergence of informal competitions, institutionalisation through international federations, and the standardisation of rules within the ISMF. Its inclusion in the programme of the 2026 Winter Olympic Games marked the sport's legitimisation, accompanied by technological advancements in equipment, increased professionalisation and more complex competition formats. Ski mountaineering is a highly dynamic sport that integrates the traditions of mountain culture, modern innovations and the requirements of the international Olympic movement.

The development of ski mountaineering is characterised by a rapid rise in popularity, a shift towards short and highly dynamic competition formats, an increase in the intensity of physical exertion, and the active technological advancement of sports equipment.

The inclusion of the sport in the Olympic programme, a reduction in the duration of competition formats by

90-95%, an increase in the intensity of exertion by 25-35% and a reduction in the weight of equipment by 20-30% reflect its transformation into a high-speed, media-oriented discipline that combines sporting performance and technological innovation. Ski mountaineering is viewed as a holistic training system, where results are determined by the interplay of an athlete's endurance, strength, coordination and technical skill in a mountain environment. The training process includes aerobic workouts to develop basic endurance, interval climbs to raise the anaerobic threshold, strength exercises for movement stability, as well as technical and transitional elements to optimise speed of action. In addition, long training days and back-to-back sessions are used to simulate fatigue. The combination of these methods ensures comprehensive adaptation of the body, building the ability to perform physical work effectively in challenging and unpredictable mountain conditions, whilst maintaining the athlete's technical precision and performance capacity.

Ski mountaineering shares common features with other endurance sports in the mountains, such as trail running, mountain running and cycling, notably the predominance of aerobic endurance and the need to perform effectively in conditions of hypoxia and challenging terrain. At the same time, its specificity lies in the combination of cyclic movements using ski equipment, which alters the biomechanics of movement, as well as in the high demands on technical and traversing skills, decision-making in a changing mountain environment, and the coordination of upper and lower limb movements. This results in a more comprehensive and multi-level nature of training compared to other endurance sports. The limitation of the study lies in its focus solely on the theoretical analysis of international sources without the inclusion of primary empirical data or experimental testing of athletes. Prospects for further research lie in studying the impact of digital monitoring technologies (GPS tracking, biometric sensors and load analysis systems) on the effectiveness of training and competitive performance in ski mountaineering.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Almqvist, A., Kalliorinne, K., Supej, M., Sjödahl, M., & Holmberg, H.C. (2025). A tribological perspective on friction and performance in Olympic snow and ice sports. *Sport Sciences for Health*, 21, 3229-3241. doi: 10.1007/s11332-025-01533-4.

[2] Alpenglow Expeditions. (n.d.). *Three steps to start ski mountaineering*. Retrieved from https://surl.li/svdtod.

[3] Batyrbekov, N., Zakiryanov, B., Ageleuova, A., Kadyrbekova, D., & Shalabayeva, L. (2024). Development of sports tourism in Kazakhstan to promote a healthy lifestyle among the younger generation, using rock climbing as an example. *Retos*, 51, 311-318.

[4] Bortolan, L., Pellegrini, B., Verdel, N., Holmberg, H.C., & Supej, M. (2023). Development of equipment for ski mountaineering, a new Olympic event. *Applied Sciences*, 13(9), article number 5339. doi: 10.3390/app13095339.

[5] Bortolan, L., Savoldelli, A., Pellegrini, B., Modena, R., Sacchi, M., Holmberg, H.-C., & Supej, M. (2021). Ski mountaineering: Perspectives on a novel sport to be introduced at the 2026 Winter Olympic Games. *Frontiers in Physiology*, 12, article number 737249. doi: 10.3389/fphys.2021.737249.

[6] Bortolotti, A., Jreij, A., Mazza, F., & Vecchi, V. (2024). Sports as a practice for well-being: The diversification of tourism through the integration of sport, wellness, and health. In A. Arcidiacono & S. Di Vita (Eds.), *Beyond the 2026 Winter Olympic Games. Mega event planning* (pp. 63-81). Singapore: Palgrave Macmillan. doi: 10.1007/978-981-99-8092-5_5.

[7] Cheng, M., Zhang, L., & Li, D. (2023). Analysis of the coupled and coordinated development of sports and tourism industries and the driving factors. *Scientific Reports*, 13, article number 16725. doi: 10.1038/s41598-023-44025-6.

[8] Ciomag, R.V., & Pop, C. (2024). Cultural and sporting characteristics of countries participating in sports competitions. *Marathon*, 16(1), 19-26. doi: 10.24818/mrt.24.16.01.02.

[9] Dynafit. (2025). *ISMF World Cup: The road to the 2026 Olympics*. Retrieved from https://www.dynafit.com/olympics-2026-and-ismf-world-cup.

[10] Ellmer, E., Ojala, A.L., & Watson, M. (2024). Challenging the norm: Sporting megatrends and their implications for athlete learning and coach development. In *The Routledge handbook of coach development in sport* (pp. 420-433). New York: Routledge. doi: 10.4324/9781003160939.

[11] Encyclopaedia Britannica. (n.d.). *Ski mountaineering*. Retrieved from https://surl.li/dvnjth.

[12] Fossa, G., Günther, F., & Rollandi, A. (2025). A sport and heritage corridor for the Valtellina Olympics. In *Small-town renaissance: Bridging technology, heritage and planning in shrinking Italy* (pp. 97-110). Cham: Springer. doi: 10.1007/978-3-031-89786-3_5.

[13] Gao, B., Wang, W., & Liu, Z. (2025). Enhancing the efficiency of venue resource allocation for university ice and snow sports education through digitalisation. *Intelligent Decision Technologies*, 19(5), 3369-3383. doi: 10.1177/18724981251348212.

[14] Gąsior, J.S., Gąsienica-Józkowy, M., Młyńczak, M., Rosoł, M., Makuch, R., Baranowski, R., & Werner, B. (2024). Heart rate dynamics and asymmetry during sympathetic activity stimulation and post-stimulation recovery in ski mountaineers – a pilot exploratory study. *Frontiers in Sports and Active Living*, 6, article number 1336034. doi: 10.3389/fspor.2024.1336034.

[15] Hou, W., Li, X., Wen, Y., & Du, X. (2024). Global research trends in skiing from 1974 to 2023: A bibliometric analysis. *Heliyon*, 10(15), article number e35471.
[16] International Olympic Committee. (2021). *Ski mountaineering added to the Milano Cortina 2026 sports programme*. Retrieved from https://www.anocolympic.org/olympic-movement/ski-mountaineering-added-to-the-milano-cortina-2026-sports-programme/.
[17] International Ski Mountaineering Federation. (2023). *ISMF World Cup calendar 2023/2024*. Retrieved from https://ismf-ski.com/the-ismf-announces-the-race-calendar-for-the-season-2023-2024/.
[18] International Ski Mountaineering Federation. (2026). *Media guide: Ski mountaineering – Milano Cortina 2026 (Version 2.2)*. Retrieved from https://ismf-ski.com/wp-content/uploads/2026/02/ISMF-Media-Guide-Ski-Mountaineering-MICO26-V2.2.pdf.
[19] International Testing Agency. (n.d.). *International Ski Mountaineering Federation (ISMF)*. Retrieved from https://ita.sport/partner/international-ski-mountaineering-federation-ismf/.
[20] Jiang, Y., Lyu, C., Chen, W., & Wen, J. (2023). Following mega sports events on social media impacts Gen Z travellers' sports tourism intentions: The case of the 2022 Winter Olympic Games. *Tourism Recreation Research*, 50(2), 282-296. doi: 10.1080/02508281.2023.2274155.
[21] Johnston, S. (2024). *Training for skiing*. Retrieved from https://evokeendurance.com/resources/training-for-skiing/.
[22] Kan, D.S. (2024). Historical conditions of Ukraine's tourism and recreation sector formation and its development in the era of sustainable multimodal mobility. *E3S Web of Conferences*, 508, article number 08024.
[23] Lasshofer, M., Seifert, J., Wörndle, A.-M., & Stöggl, T. (2023). Heel riser height and slope gradient influence the physiology of ski mountaineering – a laboratory study. *Frontiers in Physiology*, 14, article number 1159728. doi: 10.3389/fphys.2023.1159728.
[24] Leber, R. (2024). Winter sport tourism: An ecological and economic point of view. In *International perspectives in sport tourism management* (pp. 81-96). London: Routledge. doi: 10.4324/9781003476658.
[25] Li, L. (2023). Challenges and countermeasures of eco-sports tourism in Ganzi prefecture in the post-epidemic period. *Academic Journal of Humanities & Social Sciences*, 6(23), 54-58. doi: 10.25236/AJHSS.2023.062309.
[26] Lidström, I. (2025). Modern skis in nostalgic landscapes: The technological development of Swedish cross-country skiing, 1892-1932. *Scandinavian Journal of History*, 50(3), 268-290. doi: 10.1080/03468755.2024.2447297.
[27] Melo, R., Van Rheenen, D., & Gammon, S.J. (2023). Nature sports: Current trends and the path ahead. In *Nature Sports* (pp. 131-140). London: Routledge. doi: 10.4324/9781003432586.
[28] Menz, V., Niedermeier, M., Stehle, R., Mugele, H., & Faulhaber, M. (2021). Assessment of maximal aerobic capacity in ski mountaineering: A laboratory-based study. *International Journal of Environmental Research and Public Health*, 18(13), article number 7002. doi: 10.3390/ijerph18137002.
[29] Miao, Z., & Ge, G. (2023). Research on the development of sports in the age of artificial intelligence. *Power*, 5(7), 6-11. doi: 10.25236/FSR.2023.050702.
[30] Nevicato, M., Froissart, T., & Saint-Martin, J. (2025). When ski touring became multifaceted at the turn of the twenty-first century. *Loisir et Société/Society and Leisure*, 48(2), 172-191. doi: 10.1080/07053436.2025.2530805.
[31] New South Wales Institute of Sport. (2022). *Ski performance: Fatigue, pacing and proper falling strategies*. Retrieved from https://www.nswc.ca/wp-content/uploads/2022/01/Ski-Performance_-Fatigue-Pacing-and-Proper-Falling-Strategies.pdf.
[32] Nima, L. (2023). Analysis of the influence of the sports community on individual sports training based on social support theory. *SHS Web of Conferences*, 171, article number 03017. doi: 10.1051/shsconf/202317103017.
[33] Peak Experience. (n.d.). *How to train for ski touring*. Retrieved from https://peak-ex.co.nz/how-to-train-for-ski-touring/.
[34] RMI Expeditions. (n.d.). *Interval training for endurance in mountaineering*. Retrieved from https://www.rmiguides.com/rmi-knowledge-hub/interval-training-for-endurance-in-mountaineering/.
[35] Rotllan, C., & Viscor, G. (2023). Winter sports injuries in elite female athletes: A narrative review. *International Journal of Environmental Research and Public Health*, 20(10), article number 5815. doi: 10.3390/ijerph20105815.
[36] Schöffl, V.R., Zimmermann, P., Küpper, T., & Lutter, C. (2023). Ski mountaineering – scientific knowledge of this new Olympic sport: A narrative review. *Current Sports Medicine Reports*, 22(2), 61-66. doi: 10.1249/JSR.0000000000001038.
[37] Si, G., Zhang, L., Huang, Z., Gao, Z., Ge, Y., & Zhang, C.Q. (2025). Reflections on two decades of psychological services for Chinese Olympic teams: Decisive variables and major trends. *Sport & Exercise Psychology Review*, 20(1), 20-37. doi: 10.53841/bpssepr.2025.20.1.20.
[38] Tarabini, M., Gorla, C., & Scaccabarozzi, D. (2026). *Sport engineering in ski mountaineering races*. Retrieved from https://www.mecc.polimi.it/en/magazine/sport-engineering-in-ski-mountaineering-races.
[39] Tønnessen, E., Sandbakk, Ø., Sandbakk, S.B., Seiler, S., & Haugen, T. (2024). Training session models in endurance sports: A Norwegian perspective on best practice recommendations. *Sports Medicine*, 54, 2935-2953. doi: 10.1007/s40279-024-02067-4.
[40] Tribuna. (n.d.). *Ski mountaineering: A new Olympic discipline – what kind of sport is it?* Retrieved from https://ua.tribuna.com/uk/others/blogs/3161162-skialpinizm-nova-olimpiyska-dystsyplina-shcho-tse-za-vyd-sport/.
[41] Tsypko, V., Vasylchuk, V., Gedin, M., Kan, D., & Lavrynovych, E. (2024). Historical conditions of Ukraine's tourism and recreation sector formation and its development in the era of sustainable multimodal mobility. *E3S Web of Conferences*, 508, article number 08024. doi: 10.1051/e3sconf/202450808024.

[42] Zhao, C., & Shen, H. (2024). The moderating effect of ski influencers on ski tourism intention. *Sage Open*, 14(2). doi: 10.1177/21582440241242318.
[43] Zhipeng, L., Tao, Y., Cuixia, Y., & Kaidi, Z. (2025). Comparative review on sports tourism research in Chinese and international journals: A bibliometric and content analysis. *Journal of Sport & Tourism*, 29(4), 310-332. doi: 10.1080/14775085.2025.2595959.
[44] Zhouxiang, L. (2024). VR sports games: An overview. *Asian Journal of Sport History & Culture*, 3(3), 245-265. doi: 10.1080/27690148.2024.2351216.

Лижний альпінізм як новий вид олімпійської програми: тенденції розвитку та особливості підготовки спортсменів

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Анотація. Метою дослідження було виявлення характерних рис організації підготовки спортсменів у лижному альпінізмі на основі тенденцій його розвитку в контексті набуття олімпійського статусу. Методологія дослідження базувалася на використанні історико-логічного, аналітико-синтетичного, структурно-функціонального та узагальнювально-порівняльного методів, що забезпечили комплексний аналіз еволюції лижного альпінізму, сучасних тенденцій його розвитку та специфіки підготовки спортсменів у гірських умовах. Було досліджено, що лижний альпінізм еволюціонував від прикладного способу пересування в гірських умовах до структурованого міжнародного виду спорту, що поєднує альпіністські техніки, лижну підготовку та високі вимоги до фізичної витривалості. Його інституціоналізація через міжнародні федерації, стандартизацію змагань і включення до олімпійської програми відображає перехід до сучасної високотехнологічної дисципліни, інтегрованої в систему світового спорту. Було виокремлено, що сучасний розвиток лижного альпінізму характеризується швидким зростанням популярності, переходом до коротких високодинамічних форматів змагань і суттєвим підвищенням інтенсивності фізичних навантажень. Одночасно відбувається технологізація спорядження та інтенсифікація тренувального процесу, що разом із включенням до олімпійської програми визначає трансформацію виду спорту в медійно привабливу та високоспеціалізовану дисципліну. Його включення до олімпійської програми та скорочення тривалості змагальних форматів на 90-95 % відображають трансформацію у високошвидкісну та технологічно орієнтовану дисципліну з акцентом на медійність і ефективність. Було виявлено, що у системі підготовки поєднуються витривалість, сила, координація та технічні навички, що забезпечує комплексну адаптацію спортсменів до складних гірських умов і змінного навантаження. Практичне значення роботи полягає у можливості використання отриманих результатів для удосконалення системи тренувальної підготовки спортсменів у лижному альпінізмі та інших гірських видах циклічної витривалості для підвищення їхньої фізичної працездатності, технічної ефективності та адаптації до складних умов середовища

Ключові слова: аеробна витривалість; гірські умови; біомеханіка руху; фізіологічні навантаження; тренувальна підготовка

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 30.12.2025.Revised: 31.03.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.51-057.87
DOI: 10.69587/tppcs/1.2026.58

Hiking in the Ukrainian Carpathians as a form of active recreation and a means of developing physical endurance among school pupils and university students

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Abstract. The purpose of the study was to assess the effect of a three-day hike in the Ukrainian Carpathians on physical endurance indicators and its recreational effect among school pupils and university students. The participants were 120 young people (60 pupils and 60 students) who completed a three-day, 37 km route (Dilove village – Mount Pip Ivan – Dilove village), with elevations ranging from 350 m to 1,936 m above sea level. Functional status was assessed using the Harvard Step Test, the 12-minute Cooper test, continuous heart-rate monitoring, a Likert-scale questionnaire, and methods of mathematical statistics. After the hike, the Harvard Step Test Index increased significantly ($p < 0.001$), by 12.4% among pupils and 14.2% among students; the Cooper-test distance increased by 8.8% in both groups. Cardiorespiratory measurements recorded more economical effort among students, whose mean heart rate while walking was lower (134.2 ± 8.5 bpm compared with 138.4 ± 9.2 bpm among pupils) and whose pulse returned to 100 bpm sooner ($p < 0.001$). Load intensity correlated positively with gains in endurance ($\rho = 0.74$ among pupils and $\rho = 0.69$ among students), in keeping with a dose-dependent training effect. Subjective assessments likewise pointed to considerable recreational value: more than 88% of participants stated that they experienced psychological recovery, while 91.7% of pupils and 96.7% of students wished to repeat the hike. The practical importance of these results lies in the scientific justification of three-day mountain hikes as an effective way of strengthening physical education. The data may assist teachers and coaches in differentiating physical loads for different age groups, and specialists developing health-enhancement programmes aimed at reducing physical inactivity and improving young people's cardiorespiratory function

Keywords: adaptation; training effect; age differences; sex differences; cardiorespiratory system

Introduction

The relevance of this subject arises from recent changes in students' daily lives, in which the predominance of digital technologies displaces habitual physical activity and creates risks to physical health. This situation increases the need for nature-oriented forms of physical education that support both physical health and psycho-emotional recovery. Despite the popularity of active tourism, the academic literature provides limited coverage of the systematic effects of sustained physical exertion in specific natural settings on functional status. The development of physical endurance

Suggested Citation: Polishchuk, V., Palatnyi, I., & Ryzhyk, R. (2026). Hiking in the Ukrainian Carpathians as a form of active recreation and a means of developing physical endurance among school pupils and university students. *Theory and Practice of Physical Culture and Sports*, 5(1), 58-68. doi: 10.69587/tppcs/1.2026.58.

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while traversing difficult landscapes also requires more detailed and integrated analysis. The natural features of the Ukrainian Carpathians provide appropriate conditions for multi-day walking routes within active recreation programmes. Unlike short excursions, mountain hikes produce a sustained physiological load that can improve young people's aerobic capacity and strengthen overall physiological resilience in a demanding educational environment.

O. Kolotukha (2024) reviewed nature-oriented tourism and active recreation. The researcher linked participation in such activities with greater physical activity, including more daily walking among groups selecting natural routes. The main forms of nature-oriented activity were also systematised, identifying directions for subsequent empirical studies. M. Fesyk (2024) analysed the influence of sports tourism on national-patriotic education in the Volyn region. The study described a positive effect of tourism activities on socially responsible behaviour among adolescents. Questionnaire data and pedagogical observation provided quantitative evidence of positive changes in participants' motivation. V. Petryshyn (2025) considered organisational forms of tourism in adolescents' educational environment and concluded that regular hikes improved physical fitness. The author developed a classification of tourism organisation formats (curricular, extracurricular, and club-based) with practical value for educational institutions.

E. Rudenko (2024) investigated the problems and prospects of sports tourism development in Ukraine, focusing on Carpathian hiking routes and their role in strengthening young people's endurance. Key barriers to the development of the sector were identified, including financial, material-technical, and staffing constraints, and ways of addressing them were proposed. D.M. Lolowang *et al.* (2025) conducted a systematic review of innovative approaches to physical fitness teaching involving technology and gamification. After analysing 48 sources, the authors identified digital tools that increased student engagement and supported continued physical exercise without loss of motivation. M. Molokáč *et al.* (2022) analysed tourists' preferences when selecting hiking routes. Safety and natural attractiveness were the main criteria. A survey of 387 respondents and cluster analysis distinguished three tourist types with different preferences. A. Federici (2021) focused on safety in outdoor recreation. The study concluded that controlled physical exertion in mountain terrain reduced injury risk and assisted adaptation to stressors. The paper proposed recommendations on gradual load progression and the prevention of hypothermia in the mountains. K. Marsh (2025) evaluated the influence of a mountain-biking programme on social-emotional learning among schoolchildren. The results linked regular outdoor excursions with more responsible attitudes and with the objectives of hiking. A mixed-method approach assessed the programme against four social-emotional skill indicators. R. Puhakka (2021) explored students' participation in outdoor recreational activity and its effect on subjective well-being. Time spent in natural surroundings correlated positively with psychological recovery indicators. Using the standardised REST-Q questionnaire, the researcher noted that the greatest effect occurred after 3-5 hours of continuous time in forest or mountain settings. N. Labuschagné *et al.* (2025) assessed the relationship between active recreation, leisure boredom, and life satisfaction among students. Regular hiking was associated with lower boredom levels. Correlation analysis linked a one-point reduction in boredom with a 0.34-point increase in life satisfaction ($p < 0.01$).

Nevertheless, the literature provided insufficient quantitative evidence on changes in physical endurance, including heart rate, recovery indicators, and aerobic capacity, among school pupils and university students after an intensive three-day high-altitude hike in the Ukrainian Carpathians. A discrepancy remained between the stated importance of active tourism in educational programmes and the absence of empirical data on the graded effect of such activities on endurance development. Previous works were also limited by their reliance primarily on subjective assessment methods, such as questionnaires and reflection, without standardised physiological tests. The study aimed to determine how a three-day hike in the Ukrainian Carpathians affected physical endurance indicators and the recreational effect among school pupils and university students. The objectives were to assess changes in physical endurance using the Cooper test and the Harvard Step Test before and after the hike; analyse the physiological load during the route using heart-rate indicators and pulse-recovery speed; identify differences in participants' adaptive responses by age and sex; and assess subjective indicators of the recreational effect and psychological recovery using questionnaire data.

Materials and Methods

The study was conducted from May to October 2025. The study comprised three successive stages: preparatory (01.05.2025-31.05.2025), involving sample formation, medical examination, and initial testing of endurance indicators; main (01.06.2025-31.08.2025) – a series of identical three-day hikes for separate small groups of participants (15-20 individuals) under comparable load and safety conditions; and final (01.09.2025-30.10.2025) – repeat testing three days after each group returned, followed by the collection, systematisation, and statistical processing of the results. This period covered a series of identical three-day hikes for different groups of participants, together with preliminary testing, data collection, and statistical processing. The sample comprised 120 participants divided into two groups: school pupils (60 participants aged 14-17 years, including 30 boys and 30 girls) and university students (60 participants aged 18-25 years, including 30 male and 30 female students). All participants attended secondary or higher education institutions in Ivano-Frankivsk. Inclusion criteria were the absence of medical contraindications to sports tourism, confirmed by a medical certificate; voluntary written consent to participate, with parental or legal representative consent for minors; and no regular participation in organised mountain hikes during the preceding 12 months. Exclusion criteria were chronic cardiovascular or respiratory disease, acute inflammatory conditions at the beginning of the study, and musculoskeletal injuries limiting physical activity. The sampling method was non-random (purposive); groups were formed by selecting all individuals who met the inclusion criteria and had applied to take part in the hiking programme. Ethical requirements were observed throughout data collection. Participation was voluntary and required informed consent. Data

anonymity and confidentiality were ensured in accordance with national legislation. All procedures complied with ethical standards for studies involving human participants under The Declaration of Helsinki (2024).

The study programme involved a three-day mountain hike along the route Dilove village – Mount Pip Ivan – Dilove village, covering 37 km, with a mean daily distance of approximately 12-14 km and elevations ranging from 350 m to 1,936 m above sea level. Walking time was 5-7 hours per day, with breaks every 45 minutes at a pace of 2.5-3.0 km/h. The daily dietary provision had a uniform target energy value of 3,500 kcal, the fluid intake target was 2.5 L, and all participants received a complete set of specialised equipment. Physical endurance was tested two weeks before the hike and three days afterwards using the Harvard Step Test (step height 40/50 cm, 5 min, 30 steps/min), with calculation of the Harvard Step Test Index (HSTI) according to the standard formula, and the 12-minute Cooper test conducted in a stadium. During the hike, heart rate (HR) was monitored in 30% of participants using Polar H10 heart-rate monitors and Garmin Fenix 7 watches; mean and maximum values and recovery time to 100 bpm were recorded. A five-point Likert-scale survey of subjective condition was administered to all 120 participants three days after the hike. Participants rated their agreement (from 1 "strongly disagree" – to 5 "strongly agree"), with the statements: "my physical condition improved", "my fatigue level decreased", "I experienced psychological recovery", and "I was satisfied with the recreation". Responses were grouped as follows: scores of 1-2 were classified as "disagree", a score of 3 – as "neutral/difficult to answer", and scores of 4-5 – as "agree". The limitations of the study included a relatively short post-load observation period, the influence of individual metabolism on dietary assimilation, and variable high-altitude weather conditions that could alter hiking intensity.

Statistical analysis was performed in IBM SPSS Statistics version 28.0 (IBM Corp., USA). Distributional normality for quantitative variables was tested using the Shapiro-Wilk test. Where distributions were normal ($p > 0.05$), paired Student's t-tests were applied to compare pre- and post-hike indicators within each group, and independent-samples t-tests were applied to compare pupils and students. Variables whose distributions differed from normality ($p \leq 0.05$) were analysed using the non-parametric Wilcoxon signed-rank test for related samples and the Mann-Whitney U test for independent samples. Statistical significance was set at $\alpha = 0.05$. Confidence intervals for mean differences were calculated at the 95% confidence level. The correlation between load intensity (mean HR during the hike) and the increase in endurance indicators (ΔHSTI) was assessed using Spearman's rank correlation coefficient. No correction for multiple-comparison error was applied because no more than three comparisons were performed within any single hypothesis.

Results

Changes in physical endurance indicators among school pupils and university students before and after a three-day hike in the Ukrainian Carpathians

Mountain hiking imposes a specific load on the cardiorespiratory system through the combined effects of sustained muscular work, hypoxia, and temperature variation (Mozolev, 2025). Adaptation to these conditions depends on circulatory-regulation mechanisms that differ by age: chronotropic responses predominate among adolescents, whereas inotropic mechanisms assume a greater role among adults (Perrin-Malterre *et al.*, 2021). Regular participation in sports tourism promotes improvement in physical fitness (Khomenko, 2023). Pupils and students differ in morphofunctional maturity, which determines their adaptive reserves. Sex differences affect absolute endurance indicators, although relative gains in adaptive values may be similar in both sexes. Table 1 presents changes in endurance among the groups during the experiment.

Table 1. Endurance indicators among school pupils and university students before and after a three-day hike in the Ukrainian Carpathians (M ± SD)

Group	Indicator	Before the hike	After the hike	Absolute increase	Relative increase (%)
Pupils (aged 14-17 years) (n = 60)	HSTI, conventional units	68.4 ± 8.2	76.9 ± 7.5	+8.5	+12.4
	Cooper test, m	2,150 ± 230	2,340 ± 210	+190	+8.8
Students (aged 18-25 years) (n = 60)	HSTI, conventional units	74.2 ± 7.8	84.7 ± 7.1	+10.5	+14.2
	Cooper test, m	2,380 ± 250	2,590 ± 230	+210	+8.8

Source: compiled by the authors based on the experimental data

The changes in the indicators point to a marked training effect of the mountain hike in both participant groups. The identical relative increase in Cooper-test distance suggests that three days of intensive aerobic activity at altitude stimulate oxygen-transport function irrespective of age and initial fitness level. Short mountain hikes may therefore offer a practical way of rapidly mobilising young people's aerobic reserves. By contrast, HSTI was more sensitive to age differences, which may be linked to the greater morphofunctional maturity of the students. In the 18-25 age group, a marked positive trend in recovery processes was observed, indicating better autonomic regulation of heart rate and more effective utilisation of inotropic mechanisms for myocardial adaptation to exercise compared with adolescents. Among students, the increase in the recovery index exceeded the rate of increase in aerobic capacity, whereas among pupils, the two indicators changed more evenly. The hike imposed a greater stress load on the younger group, for whom functional recovery and the attainment of supercompensation required more time. The results suggest that a three-day hike in the Carpathians provides recreational benefits and can strengthen physical education. Table 2 presents the analysis by sex.

Table 2. Endurance indicators by sex and age (M ± SD)

Subgroup (n = 30)	Indicator	Before the hike	After the hike	Increase
Male pupils	HSTI	72.1 ± 7.6	81.3 ± 6.9	+9.2
Female pupils	HSTI	64.7 ± 7.9	72.5 ± 7.3	+7.8
Male pupils	Cooper test (m)	2,310 ± 210	2,510 ± 190	+200
Female pupils	Cooper test (m)	1,990 ± 190	2,170 ± 180	+180
Male students	HSTI	78.4 ± 7.1	89.8 ± 6.5	+11.4
Female students	HSTI	70.0 ± 7.3	79.6 ± 6.8	+9.6
Male students	Cooper test (m)	2,570 ± 230	2,800 ± 210	+230
Female students	Cooper test (m)	2,190 ± 210	2,380 ± 200	+190

Note: each subgroup comprised n = 30 participants
Source: compiled by the authors based on the experimental data

Male pupils and male students had consistently higher absolute values at each stage of the experiment. This difference corresponds to physiological sexual dimorphism: a larger cardiac volume, higher haemoglobin concentration, and greater skeletal muscle mass support more intensive oxygen delivery during exertion. Despite substantial differences in baseline values, the changes in aerobic endurance measured by the Cooper test were almost identical for males and females. Similar relative rates of improvement suggest that the capacity to develop aerobic performance in response to mountain exertion is not confined by sex. Female pupils and female students responded to the stimulus as effectively as their male counterparts, in proportion to their respective functional limits.

The difference in recovery speed, measured by HSTI, in favour of male pupils and male students warrants separate attention. Their more rapid return to normal HR may be associated with a stronger sympathoadrenal response, accelerating functional stabilisation after exercise stops. Female pupils and female students exhibited a more gradual adaptation, possibly linked to hormonal features that help prevent excessive depletion of resources during prolonged work. Although both sexes experienced a training effect, their biological recovery patterns therefore differed and should be borne in mind when rest periods on the route are planned. Changes within each subgroup were statistically significant according to the paired t-test (all $p < 0.001$). Table 3 compares age groups separately for males and females.

Table 3. Comparison of increases in endurance indicators between pupils and students by sex (independent-samples t-test)

Subgroups	Indicator	Difference in increases	95% CI	t-value	p-value
Male pupils – male students	ΔHSTI	2.2	[1.1; 3.3]	3.71	<0.001
Female pupils – female students	ΔHSTI	1.8	[0.8; 2.8]	3.32	0.002
Male pupils – male students	ΔCooper (m)	30	[10; 50]	2.98	0.004
Female pupils – female students	ΔCooper (m)	10	[-8; 28]	1.09	0.278

Note: square brackets contain the 95% confidence interval for the difference in mean increases between groups; each sex-based subgroup comprised 30 participants – male pupils, male students, female pupils, and female students; an interval that does not cross zero represents a statistically significant difference at $\alpha = 0.05$
Source: compiled by the authors based on the experimental data

The statistical results varied by age category. Significant differences in HSTI increases for both male and female comparisons point to more intensive recovery processes among university students than among school pupils. This pattern accords with greater functional maturity of autonomic mechanisms regulating heart rhythm at the age of 18-25 years and, consequently, faster stabilisation after the route. Cooper-test results differed in the male comparison: male students improved more rapidly than male pupils, whereas no statistically significant difference emerged between female students and female pupils. This may reflect earlier stabilisation of female aerobic potential, while males retain considerable scope for increasing endurance into university age.

Baseline HSTI values placed students in the "above average" category and pupils in the "average" category. After the experiment, students reached the "high" category, while pupils reached "above average". A similar change occurred in the Cooper test: students moved from "good" to "excellent", while pupils improved from "below average" to "average". These data indicate an overall improvement in young people's functional status after participation in the mountain hike. Improvement in physical fitness across all subgroups reinforces the value of high-altitude natural factors for mobilising aerobic reserve. However, the results should be interpreted as a composite effect, including repeated testing, mobilisation of volitional effort, and individual adaptation, rather than solely as a consequence of muscular activity. Faster recovery among students than pupils suggests more efficient cardiovascular activity, a central feature of adaptive processes in a more mature organism. However, similar relative changes between male and female pupils, and between male and female students, provide little evidence of a pronounced sex-specific difference in the overall rate of endurance improvement after outdoor recreation.

Analysis of physiological load during the mountain route using heart rate and recovery time indicators

Adaptation of the cardiovascular system to regular aerobic physical loads is expressed as a reduction in heart rate

during resting and during standard submaximal work (Kashelyuk, 2021). Heart rate is an objective indicator of physical-load intensity during hiking trips (Telford & Potter, 2011). Real-time HR monitoring traced the cardiovascular response to movement through mountain terrain with varied relief and elevation changes. The state of the autonomic nervous system determines the rate of HR recovery after muscular work ceases (Bilyk, 2025).

In sports tourism, working HR values of 120-150 bpm correspond to an aerobic-load zone conducive to endurance development. Values above 160 bpm signal a shift towards a mixed aerobic-anaerobic zone and may hasten fatigue. The time required for HR to recover after activity ends characterises autonomic regulation and training status: faster return towards resting values corresponds to better conditioning. Among young people without regular physical training, HR commonly returns to 100 bpm within 5-10 minutes; among trained individuals, this period is reduced to 2-4 minutes. The training effect on endurance depends on the intensity of effort within the aerobic energy-supply zone. O. Olkhovyi *et al*. (2024) linked mean load intensity, represented by mean HR while completing the route, with post-hike gains in endurance, in keeping with a dose-dependent effect. The optimal mean HR range for developing endurance was 130-150 bpm among students, whereas for pupils aged 14-17 years it was 120-140 bpm because of age-related differences in heart-rhythm regulation. The present study continuously monitored HR in 36 randomly selected participants, comprising 18 pupils and 18 students. Recording took place from 08:00 to 18:00 on all three days of the hike, using the mean HR for each hour of walking. Table 4 presents mean HR values and recovery times for the two groups.

Table 4. Heart rate and recovery-time indicators during the three-day hike (M ± SD)

Indicator	Pupils (n = 18)	Students (n = 18)	Difference	p-value
Mean HR per hour of walking, bpm	138.4 ± 9.2	134.2 ± 8.5	-4.2	0.042
Maximum HR (on ascents), bpm	172.6 ± 8.7	168.3 ± 7.9	-4.3	0.038
Recovery time to 100 bpm, min	6.8 ± 1.4	5.2 ± 1.1	-1.6	<0.001

Source: compiled by the authors based on the experimental data

Cardiometric monitoring data for both groups remained within the aerobic energy-supply zone. Students had lower mean and maximum HR values, corresponding to more economical cardiac work than among pupils. This difference is associated with greater maturity of adaptive mechanisms at 18-25 years: an equivalent amount of work was completed under less functional strain. The largest inter-group difference concerned pulse-recovery speed. Faster return of HR towards normal values among students is compatible with better autonomic regulation and stronger parasympathetic influence after physical activity. The longer recovery period among pupils may be explained by sympathicotonia characteristic of adolescence, resulting in a higher "physiological cost" of traversing mountain terrain. These results point to substantial functional reserves among students. Among pupils, the same physical activity acts as a stronger stimulus and should be accounted for when selecting walking pace and rest duration on difficult sections of the route. Hourly mean values were subsequently analysed to clarify HR changes during each day of the hike; Table 5 presents the results.

Table 5. Changes in mean HR (bpm) by day of the hike (M ± SD)

Group	Day 1	Day 2	Day 3	Δ Day 3 – Day 1	p-value (Day 1 / Day 3)
Pupils (n = 18)	142.1 ± 9.8	138.9 ± 9.3	134.2 ± 8.8	-7.9	0.008
Students (n = 18)	137.5 ± 8.9	134.8 ± 8.4	130.3 ± 8.1	-7.2	0.012

Source: compiled by the authors based on the experimental data

Across the three days, mean HR gradually decreased in both groups. The steady decline in working pulse points to rapid adaptation to the combination of physical load and high-altitude conditions. Cardiac strain was greatest during the first half of the first day, when participants negotiated the most difficult terrain and underwent initial acclimatisation. By the third day, the chronotropic response had stabilised noticeably: peak HR values on sections with a comparable gradient were substantially lower than at the outset. This pattern illustrates the ability of young people to adapt rapidly to hypoxia and physical exertion. By the end of the hike, the lower pulse cost of completing the route marked more economical physiological functioning. The steady decrease in mean HR in both groups also illustrates the short-term training effect of mountain hiking on autonomic regulation of heart rhythm. These data suggest that three days represent the minimum period over which an initial adaptive response becomes apparent through more efficient cardiac performance during standard muscular work on the route. The relationship between load intensity and the training effect was assessed by calculating Spearman's correlation coefficient for mean HR during the hike and the post-hike increase in HSTI; the values are presented in Table 6.

Table 6. Correlation between mean HR (bpm) and the post-hike increase in HSTI (ΔHSTI)

Group	Mean HR, M ± SD	ΔHSTI, M ± SD	ρ (Spearman)	p-value
Pupils (n = 18)	138.4 ± 9.2	8.5 ± 2.1	0.74	<0.001
Students (n = 18)	134.2 ± 8.5	10.5 ± 2.3	0.69	0.002

Source: compiled by the authors based on the experimental data

The correlation coefficient between mean HR and the increase in HSTI was $\rho = 0.74$ among pupils ($p < 0.001$) and $\rho = 0.69$ among students ($p = 0.002$). Both values represent a strong positive relationship: participants with a higher mean HR during the hike, and therefore a higher working intensity, achieved a greater increase in endurance. The relationship was linear across the HR range of 125-145 bpm. Where mean HR exceeded 150 bpm, which occurred in four pupils, HSTI no longer rose proportionately, suggesting proximity to an individual anaerobic threshold and possible overload. Exercise above 85% of maximum HR is known to overactivate the sympathetic component and impair adaptation in young people without specialised training. As only a small number of participants in this study reached this level, the overall correlation remained strong. No student exceeded a mean HR of 158 bpm, which may explain the slightly lower, though still strong, coefficient in the student group ($\rho = 0.69$). Further analysis revealed that in pupils with an average HR below 130 bpm ($n = 4$), the increase in HSTI was only 5.2 ± 1.4 units, whereas in those whose average HR was in the range of 135-145 bpm ($n = 10$), the increase reached 9.8 ± 1.7 units. The corresponding values among students were 7.6 ± 1.5 units at HR < 130 bpm ($n = 6$) and 11.9 ± 1.9 units at HR 130-140 bpm ($n = 9$). Thus, the training effect was dose-dependent: effort intensity within the aerobic zone affected the increase in endurance. In this sample, larger HSTI increases occurred among participants whose mean HR exceeded 130 bpm.

Physiological load during the three-day hike in the Ukrainian Carpathians was characterised by a mean HR of 130-140 bpm, within the aerobic zone for endurance development. Pupils had higher absolute HR values and longer recovery times than students. Mean HR declined progressively in both groups over the three days, marking acute adaptation. Its correlation with the increase in HSTI was strongly positive ($\rho = 0.74$ among pupils and $\rho = 0.69$ among students), providing evidence of a dose-dependent training effect.

Comparison of the training and recreational effects of hiking among school pupils and university students

Health-enhancing recreational activity in natural surroundings aids recovery of physical and psychological resources through the combination of physical activity and exposure to natural factors (Halamay, 2021). During multi-day hiking trips, cardiovascular function improves through more economical work and faster recovery processes (Skaliy *et al.*, 2023). Balanced use of forest areas for active recreation can increase physical activity in the population without disturbing ecological balance (Brovina & Sallaku, 2024). Regular participation by children and adolescents in active tourism activities also produces statistically significant improvements in cardiorespiratory endurance and overall physical working capacity (Martínez-Redecillas *et al.*, 2026). Table 7 presents the medians (Me) and interquartile ranges (IQR) for responses in the pupil and student groups.

Table 7. Post-hike participant survey results (Me [IQR])

Statement	Pupils (n = 60)	Students (n = 60)	p (Mann-Whitney U test)
My physical condition improved	4 [4; 5]	5 [4; 5]	0.031
My fatigue level decreased	4 [3; 4]	4 [4; 5]	0.008
I experienced psychological recovery	5 [4; 5]	5 [5; 5]	0.042
I was satisfied with the recreation	5 [4; 5]	5 [5; 5]	0.023

Note: square brackets contain the interquartile range (IQR), comprising the first (Q1) and third (Q3) quartiles [Q1; Q3], this interval covers the central 50% of participants' responses; the median (Me) is shown before the brackets
Source: compiled by the authors based on the experimental data

According to Table 7, the hike had a positive effect in both groups, with higher assessments among students. Students gave higher median ratings for most indicators and a narrower interquartile range (IQR), suggesting greater convergence in their responses; all four statements also differed significantly between groups ($p < 0.05$). Although pupils expressed satisfaction with the hike, their responses were more variable, while students were more uniform in assessing its positive effect on physical and psychological condition. Table 8 presents the percentage distribution of responses.

Table 8. Percentage of participants who agreed with the statements (%)

Statement	Pupils (% agreeing)	Students (% agreeing)	Difference (percentage points)
My physical condition improved	78.3	91.7	+13.4
My fatigue level decreased	68.3	85.0	+16.7
I experienced psychological recovery	88.3	96.7	+8.4
I was satisfied with the recreation	91.7	98.3	+6.6

Source: compiled by the authors based on the experimental data

Subjective assessments of the hike were generally positive among the young participants. Psychological recovery and overall satisfaction received the highest ratings, pointing to the considerable recreational value of mountain routes in both age groups. Students provided a greater proportion of positive assessments across all indicators, which may relate to stronger awareness of the effect of physical activity and better adaptation to the load. The difference in responses on reduced fatigue is particularly informative: the lower proportion of pupils agreeing with this statement points to a greater "physiological cost" of the hike for adolescents. For pupils, the three-day route represented an intensive physical challenge primarily; for students, it functioned more effectively as a form of

recovery. The near-unanimous satisfaction among students favours the inclusion of such activity in the educational process as a means of counteracting academic exhaustion. Low levels of negative assessment (scores of 1-2) in both groups are compatible with the safety and appropriateness of the selected route for the participants. Despite the physical difficulty, the psychological effect of time spent in natural surroundings remained an important motivation for future participation in tourism. Responses were then analysed by sex, with the proportions agreeing with each statement among male and female pupils and students presented in Table 9.

Table 9. Percentage agreeing with statements, by sex and age (%)

Statement	Male pupils (n = 30)	Female pupils (n = 30)	Male students (n = 30)	Female students (n = 30)
My physical condition improved	83.3	73.3	93.3	90.0
My fatigue level decreased	73.3	63.3	86.7	83.3
I experienced psychological recovery	90.0	86.7	96.7	96.7
I was satisfied with the recreation	93.3	90.0	100.0	96.7

Source: compiled by the authors based on the experimental data

Within the pupil group, male pupils had a higher percentage of agreement than female pupils for every statement. The differences were 10.0 percentage points for improved physical condition, 10.0 percentage points for reduced fatigue, 3.3 percentage points for psychological recovery, and 3.3 percentage points for satisfaction. Sex differences were less pronounced in the student group. Male students had slightly higher values for improved physical condition and satisfaction, while both student subgroups gave the same response level for psychological recovery. The difference in reduced fatigue was 3.4 percentage points. The highest value across all subgroups occurred among male students for satisfaction with the recreation (100%). Participants were also asked whether they wished to take part in a similar hike during the next season; Table 10 presents their responses.

Table 10. Willingness to repeat the hike in the next season

Response	Pupils (n = 60)	Students (n = 60)
Yes	55 (91.7%)	58 (96.7%)
No	3 (5.0%)	2 (3.3%)
Undecided	2 (3.3%)	0 (0.0%)

Source: compiled by the author based on the experimental data

Most participants in both groups wished to repeat the hike: 91.7% of pupils and 96.7% of students. Repeat participation was declined by 5.0% of pupils and 3.3% of students. A small number of pupils remained undecided, whereas no students selected this response. Those declining included two female pupils, one male pupil, one female student, and one male student; their reasons were lack of time (three participants) and insufficient physical fitness (two participants). Taken together, the survey responses point to a marked recreational effect of the three-day hike in the Ukrainian Carpathians in both groups. Students rated improvement in physical condition, reduced fatigue, and psychological recovery more highly than pupils. More than 90% of participants in both groups were satisfied with the recreation. In the pupil group, male pupils rated the recreational effect more highly than female pupils, while differences between male and female students were minimal. The available data therefore justify viewing a three-day hike in the Ukrainian Carpathians as a potentially effective form of active recreation and a means of short-term improvement in young people's physical endurance. Graded aerobic exertion in mountain terrain appeared to mobilise adaptive resources and improve overall physical working capacity.

Discussion

After the three-day hike in the Ukrainian Carpathians, physical endurance improved among both adolescents and university students. The principal results were increased Cooper-test and HSTI values, higher absolute indicators and faster HR recovery in the student group, and a strong relationship between load intensity, represented by mean HR, and gains in endurance. These results agree with O. Mozolev *et al.* (2020), who documented a 10-15% increase in aerobic endurance after hiking trips. The HSTI increase in the present study (12.4-14.2%) fell within this range. Comparison with O. Mozolev *et al.* (2020) also points to age-related differences in adaptation, as university students had a substantially greater capacity to mobilise functional reserves than adolescents.

The results are also comparable to those of J.K. Boggs (2024), who analysed the influence of an extracurricular adventure-education programme on upper-secondary pupils' attitudes towards active outdoor recreation. That study noted increased physical activity after a four-day programme and greater interest in tourism. A comparable response occurred in the present study: 91.7% of pupils expressed willingness to repeat the hike. However, J.K. Boggs (2024) did not measure objective physiological indicators such as HR or endurance-test results. Here, subjective ratings were accompanied by quantitative data, strengthening the conclusions. C.L. Brown (2021) conducted a pilot study of a mountain-biking adventure-therapy programme for lower-secondary pupils. The researcher observed that the eight-week programme improved psychosocial adaptation but did not produce statistically significant changes in physical endurance, attributing this to insufficient load intensity. Unlike the study by C.L. Brown (2021), the present study identified significant endurance changes,

which may be linked to mountain terrain and sustained aerobic exertion of 5-7 hours per day over three days. The terrain and the extent of physical activity, therefore, appear important for obtaining a training effect, with the duration and intensity of the hike playing a central role.

R. Jasmanedi *et al.* (2025) compared the physical fitness of pupils living in different landscape zones. The researchers documented substantially higher physical-condition indicators among young people who lived in or spent active time in mountain areas than among their peers from plain or coastal regions. The presented results correspond to those of R. Jasmanedi *et al.* (2025): three days at altitude in the Carpathians were associated with appreciable improvements in endurance-test performance. Whereas that earlier study focused on continuous exposure to the residential environment, the present data suggest that a short, intensive hike can produce a comparable adaptive effect. E.R. Malones (2024), addressing implementation of the Global Action Plan on Physical Activity, stressed the importance of integrating health-enhancing activity into young people's daily schedules to improve overall health and working capacity. The researcher linked purposeful physical activity (Physical Activity for Health and Fitness) directly with subjective well-being. In the current study, high ratings of psychological recovery (93-97% agreement) and the willingness of more than 91% of participants to repeat the hike reinforce the proposition of E.R. Malones (2024) that well-organised physical activity is perceived by young people not as an onerous load but as a means of restoring personal resources. The present data also supplement the results of E.R. Malones (2024) with quantitative changes in HR, permitting a more precise appraisal of the physiological cost of such recreational activities.

B. Zhijing *et al.* (2025) assessed the influence of recreational cycling tours on the cardiorespiratory status of Chinese students. The researchers documented that a five-day tour reduced resting HR by 8-10 bpm and increased vital capacity. In the present study, HR during the route decreased by 7.9 bpm among pupils and 7.2 bpm among students, close to the range described by B. Zhijing *et al.* (2025). The studies differ in the mode of travel: cycling imposes a somewhat different load, with lower impact on joints but higher movement speeds. Despite this difference, cardiorespiratory adaptation was similar. M.I.R. Suarlam *et al.* (2026) compared the physical fitness of primary-school pupils from rural and urban settings. Their data associated rural residence, in a more natural environment, with better endurance among pupils. Although all participants in the present study were urban residents of Ivano-Frankivsk, after the three-day hike, their endurance indicators reached the levels observed by M.I.R. Suarlam *et al.* (2026) among rural pupils. This suggests that even short-term exposure to a natural mountain setting can partially reduce fitness differences associated with permanent living conditions. M. Căsăneanu *et al.* (2025) assessed the role of climbing-wall exercise in children's balance development. Although their study concerned a different form of activity, the authors noted activation of muscle groups rarely recruited in daily activity during exercise involving vertical movement. In the conducted study, participants with lower initial fitness achieved substantial relative increases in indicators. Changes within individual subgroups follow the principle of "lower initial reserves" described by M. Căsăneanu *et al.* (2025), whereby an organism with lower baseline fitness responds more strongly to an intensive new stimulus.

D.O. Mudzakir *et al.* (2025) compared physical fitness and motivation to learn among pupils attending "nature schools" and conventional schools. Their results associated nature-school attendance with greater motivation for physical activity and better endurance. The participants in the presented study had no previous organised hiking experience, yet after the three-day walking route, 88-97% stated that they experienced psychological recovery, reflecting a positive response to outdoor activity. D.O. Mudzakir *et al.* also noted that female pupils experienced a stronger effect of contact with nature and achieved a greater relative increase in the Harvard Step Test Index. Comparison with earlier studies highlights several patterns. A three-day mountain hike markedly improved participants' endurance, in agreement with O. Mozolev (2025) and B. Zhijing (2025). Students aged 18-25 years had better adaptive capacity than pupils aged 14-17 years, which aligns with the conclusions of D.O. Mudzakir (2025) on age-related features of cardiovascular function.

Subjective assessments of the recreational effect also merit attention. The present approach combined physiological measurements, namely the Harvard Step Test, Cooper test, and HR monitoring, with an extensive questionnaire. Unlike the work of O. Mozolev (2025) and E.R. Malones (2024), which relied mainly on qualitative methods, and that of B. Zhijing (2025) and M.I.R. Suarlam (2026), which focused on physiological indicators without the subjective component, this study identified parallel positive changes in perceived well-being and objective endurance. Both age groups achieved the same relative increase in Cooper-test distance (8.8%), corresponding to a proportional change in aerobic capacity irrespective of age. Recovery measured by HSTI was more age-dependent: the increase among students (14.2%) exceeded that among pupils (12.4%), a pattern not described by either O. Mozolev *et al.* (2020) or B. Zhijing *et al.* (2025). Overall, the results correspond to most of the works discussed in relation to the positive effect of nature-oriented load on cardiorespiratory function and subjective well-being. They also distinguish age- and sex-related features of adaptation that should be addressed when comparable activities are organised. The strong positive correlation between mean HR during the hike and the increase in endurance is compatible with a dose-dependent training effect.

Conclusions

Following the three-day hike in the Ukrainian Carpathians, statistically significant improvements occurred in young people's physical endurance indicators ($p < 0.001$). Among pupils aged 14-17 years, the relative increase in the Harvard Step Test Index was 12.4%; among students aged 18-25 years – 14.2%, while Cooper-test performance increased by 8.8% in both groups. Students achieved higher absolute results throughout the study and recovered their HR more rapidly. The sex-based analysis yielded similar relative increases in male and female participants, although male subgroups had higher absolute values. Physiological load during the route remained in the aerobic zone; pupils

had a higher mean HR and a longer recovery period than students. The progressive reduction in mean HR by 7.2-7.9 bpm and recovery to 100 bpm within 5.2-6.8 minutes point to a more economical physiological response and mobilisation of the participants' adaptive resources.

The correlation between mean HR during the hike and the increase in the Harvard Step Test Index was strongly positive: $\rho = 0.74$ among pupils ($p < 0.001$) and $\rho = 0.69$ among students ($p = 0.002$). Pupils with a mean HR of 135-145 bpm ($n = 10$) achieved an HSTI increase of 9.8 ± 1.7 units, whereas pupils with HR below 130 bpm ($n = 4$) increased by only 5.2 ± 1.4 units. Among students, the increase was 11.9 ± 1.9 units at HR 130-140 bpm ($n = 9$) and 7.6 ± 1.5 units at HR below 130 bpm ($n = 6$). Questionnaire responses confirmed a marked recreational effect of the hike, with the student group giving higher subjective ratings for every criterion. Improved physical condition was selected by 78.3% of pupils and 91.7% of students; reduced fatigue by 68.3% and 85.0%, respectively. Psychological recovery received the highest values, with agreement among 88.3% of pupils and 96.7% of students. Overall satisfaction with active recreation was also very high, at 91.7% and 98.3%, corresponding to willingness to participate in similar activities again among 91.7% of pupils and 96.7% of students. These data point to a stable positive attitude towards hiking as a means of recovery and health enhancement.

The combination of intensive aerobic exertion and time in a high-altitude environment provides a strong stimulus for improving young people's cardiorespiratory function. The observed pattern of the training effect justifies the use of hiking as a scientifically grounded means of addressing physical inactivity in contemporary education. These observations justify incorporating multi-day routes into physical education programmes to increase functional reserves among pupils and students. Further research should extend mountain routes to 5-7 days to assess the course of adaptive changes and the duration of the effect more fully. A control group would also strengthen comparative analysis of endurance indicators and permit more precise separation of the effect of physical load from associated factors.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Bilyk, I. (2025). *The importance of physical activity in the formation of a healthy lifestyle of student youth*. (Master's thesis, Lesya Ukrainka Volyn National University, Lutsk, Ukraine).

[2] Boggs, J.K. (2024). *The effect of an after-school outdoor adventure education program on high school students' outdoor recreation perspective*. (Doctoral dissertation, The University of North Carolina at Greensboro, Greensboro, United States of America).

[3] Brovina, F., & Sallaku, D. (2024). Sustainable development of forest parks for active recreation: A balance between nature conservation and physical education. *Ukrainian Journal of Forest and Wood Science*, 15(3), 165-179. doi: 10.31548/forest/3.2024.165.

[4] Brown, C.L. (2021). *An adventure therapy mountain bike program for middle school students: A pilot study*. (Doctoral dissertation, University of Arkansas, Fayetteville, United States of America).

[5] Căsăneanu, M., Mihăilescu, L.N., Potop, V., Mihăilă, I., Manole, C., Mihăilescu, L.E., Rață, B. C., Mâță, L., & Rață, M. (2025). The role of climbing exercises in developing balance ability in children. *Applied Sciences*, 15(11), article number 5959. doi: 10.3390/app15115959.

[6] Federici, A. (2021). Enjoying natural environments safely: Sports, adventure, risk and safeguarding health. *Journal of Physical Education and Sport*, 21, 520-525. doi: 10.7752/jpes.2021.s1056.

[7] Fesyk, M. (2024). *National-patriotic education of the population of Volyn by means of sports tourism and orientation*. (Master's thesis, Lesya Ukrainka Volyn National University, Lutsk, Ukraine).

[8] Halamay, A. (2021). *Organization of health and recreational activities in the conditions of ski centers*. (Master's thesis, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine).

[9] Jasmanedi, R., Barlian, E., Yendrizal, Gusril, Firman, & Kurniawan, R. (2025). Analysis of physical fitness of elementary school learners in the beachside, plain, and mountain areas of Padang City. *Jurnal Penelitian Pendidikan IPA*, 11(3), 19-25. doi: 10.29303/jppipa.v11i3.10374.

[10] Kashelyuk, V. (2021). *Snow and ice types of recreation in the leisure time of young people*. (Master's thesis, National University of Ukraine on Physical Education and Sport, Kyiv, Ukraine).

[11] Khomenko, E. (2023). *Prospects of the post-war development of sports tourism in the Poltava region*. (Bachelor thesis, Poltava University of Economics and Trade, Poltava, Ukraine).

[12] Kolotukha, O. (2024). Nature-oriented tourism and active recreation. In H. Shchuka (Ed.), *Niche forms of tourism* (pp. 45-102). Berehove: Ferenc Rakoczi II Transcarpathian Hungarian University. doi: 10.58423/978-617-8143299/45-102.

[13] Labuschagné, N., Schreck, C., & Weilbach, T. (2025). Exploring the link: Active recreation, leisure boredom, and life satisfaction in South African undergraduate students. *South African Journal for Research in Sport, Physical Education and Recreation*, 47(1), 67-80. doi: 10.36386/sajrsper.v47i1.571.

[14] Lolowang, D.M., Ihsan, F., Piri, N., Kumenap, E.E., & Makadada, F.A. (2025). Innovative teaching methods in physical fitness education: Integrating technology and gamification to improve student engagement – a systematic review. *Retos*, 68, 1148-1163. doi: 10.47197/retos.v68.116064.

[15] Malones, E.R. (2024). WVSU's physical activity for health and fitness and the global action plan for physical activity. *WVSU Research Journal*, 13(1), 30-46. doi: 10.59460/wvsurjvol13iss1pp30-46.
[16] Marsh, K. (2025). *Developing social and emotional learning in middle school students: A teaching personal and social responsibility approach to a mountain biking after school program*. (Master's thesis, University of Wyoming, Laramie, United States of America).
[17] Martínez-Redecillas, E., Moral-García, J.E., Casado-Montilla, J., & Solas-Martínez, J.L. (2026). Impact of active tourism on physical activity in children and adolescents: A systematic review (2015-2025). *World*, 7(2), article number 31. doi: 10.3390/world7020031.
[18] Molokáč, M., Hlaváčová, J., Tometzová, D., & Liptáková, E. (2022). The preference analysis for hikers' choice of hiking trail. *Sustainability*, 14(11), article number 6795. doi: 10.3390/su14116795.
[19] Mozolev, O. (2025). *Preparation and conducting of sports and health-improving tourist trips with pupils and student youth*. Khmelnytskyi: Khmelnytskyi Humanitarian-Pedagogical Academy.
[20] Mozolev, O., Shorobura, I., Zdanevych, L., Hutsal, L., Marusynets, M., & Kravchuk, L. (2020). Influence of physical fitness of students on the quality of leisure organization in a sports and health tourism. *Revista Romaneasca Pentru Educatie Multidimensionala*, 12(2), 117-131. doi: 10.18662/rrem/12.2/269.
[21] Mudzakir, D.O., Ramadhan, R., Mubarok, M.Z., Effendy, F., & Widi, F.S. (2025). Comparison of physical fitness and learning motivation in nature school students and regular school students. *Journal of General Education and Humanities*, 4(3), 793-802. doi: 10.58421/gehu.v4i3.460.
[22] Olkhovyi, O., *et al.* (Eds.). (2024). *Modern views of young people on physical culture, sports and human health*. Kharkiv: Kharkiv State Academy of Physical Culture.
[23] Perrin-Malterre, C., Chanteloup, L., & Gruas, L. (2021). Outdoor recreation in a Regional Park: Types of hikers, ski tourers and snowshoers in the Hautes-Bauges (Savoie, France). *Annals of Leisure Research*, 24(2), 209-227. doi: 10.1080/11745398.2019.1682016.
[24] Petryshyn, V. (2025). *Forms of organizing tourism in the educational environment of teenagers*. (Master's thesis, Lesya Ukrainka Volyn National University, Lutsk, Ukraine).
[25] Puhakka, R. (2021). University students' participation in outdoor recreation and the perceived well-being effects of nature. *Journal of Outdoor Recreation and Tourism*, 36, article number 100425. doi: 10.1016/j.jort.2021.100425.
[26] Rudenko, E. (2024). *Sports tourism in Ukraine: Problems and prospects for development*. (Bachelor thesis, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine).
[27] Skaliy, A., Mulyk, K., Ban, Z., Ostrowski, A., & Anosova, O. (2023). Assessment of the functional state of the cardiovascular system of students during a mountain hiking trip. *Slobozhanskyi Herald of Science and Sport*, 27(3), 158-165. doi: 10.15391/snsv.2023-3.007.
[28] Suarlam, M.I.R., Hudain, M.A., & Jamaluddin, J. (2026). A comparative study of physical fitness levels among junior high school students in rural and urban areas. *ETDC: Indonesian Journal of Research and Educational Review*, 5(2), 1415-1427. doi: 10.51574/ijrer.v5i2.4618.
[29] Telford, J., & Potter, J. (2011). Adventure education: Physical exercise and health. In C. Hodgson & M. Berry (Eds.), *Adventure education* (pp. 146-165). London: Routledge. doi: 10.4324/9780203856758.
[30] The Declaration of Helsinki. (2024). Retrieved from https://www.wma.net/policies-post/wma-declaration-of-helsinki/.
[31] Zhijing, B., Skaliy, T., Ostrowski, A., Minzhanov, N., Alpysbayeva, M., & Prudnikova, M. (2025). The impact of sports and recreational hiking with bicycles on the state of the cardiorespiratory system of Chinese students. *Slobozhanskyi Herald of Science and Sport*, 29(1), 96-104. doi: 10.15391/snsv.2025-1.09.

Піші походи в Українських Карпатах як засіб активної рекреації та розвитку фізичної витривалості учнівської та студентської молоді

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Анотація. Метою дослідження була оцінка впливу триденного пішого походу в Українських Карпатах на показники фізичної витривалості та рекреаційний ефект для учнівської та студентської молоді. У дослідженні взяли участь 120 осіб (60 учнів та 60 студентів), які пройшли триденний маршрут (с. Ділове – г. Піп Іван Мармароський – с. Ділове) загальною протяжністю 37 км із перепадом висот від 350 м до 1 936 м н.р.м. Для оцінки функціонального стану використовувалися Гарвардський степ-тест, 12-хвилинний тест Купера, безперервний моніторинг частоти серцевих скорочень, опитування за шкалою Лікерта та методи математичної статистики. За результатами дослідження після походу зафіксовано статистично значуще ($p < 0,001$) зростання індексу Гарвардського степ-тесту на 12,4 % в учнів та 14,2 % у студентів, а також збільшення дистанції у тесті Купера на 8,8 % в обох групах. Аналіз кардіореспіраторної системи показав, що студенти працювали економніше, продемонструвавши нижчу середню частоту серцевих скорочень під час руху (134,2 ± 8,5 уд./хв проти 138,4 ± 9,2 уд./хв в учнів) та швидше відновлення пульсу до рівня 100 уд./хв ($p < 0,001$). Встановлено позитивний кореляційний зв'язок між інтенсивністю навантаження та приростом показників витривалості ($\rho = 0,74$ в учнів та $\rho = 0,69$ у студентів), що підтверджує дозозалежність тренувального ефекту. Суб'єктивна оцінка підтвердила високий рекреаційний потенціал заходу: понад 88 % учасників відзначили психологічне відновлення, а 91,7 % учнів та 96,7 % студентів висловили бажання повторити похід. Практична значимість результатів полягає в науковому обґрунтуванні триденних гірських походів як ефективного засобу інтенсифікації фізичного виховання. Отримані дані будуть корисними для вчителів та тренерів при диференціації фізичних навантажень для різних вікових груп, а також для фахівців, які займаються розробкою оздоровчих програм, спрямованих на подолання гіподинамії та зміцнення кардіореспіраторної системи молоді

Ключові слова: адаптація; тренувальний ефект; вікові відмінності; гендерні відмінності; кардіореспіраторна система

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 07.10.2025.Revised: 07.04.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.011-057.875:615.825
DOI: 10.69587/tppcs/1.2026.69

The effectiveness of applying a remedial physical education programme in the physical training of students at higher education institutions

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Abstract. The aim was to establish the effectiveness of applying a corrective approach in the physical education of students within higher education institutions. The methodology included a comparative analysis of traditional and corrective physical education programmes for students, as well as a pedagogical experiment conducted at Hryhorii Skovoroda University in Pereiaslav. The results confirmed the need to reorient the physical education system in higher education institutions towards individualised corrective programmes. The results showed that the implementation of a corrective programme ensures greater effectiveness in students' physical training compared to the traditional system. In the experimental group, an increase in average values was recorded across all 15 parameters studied: speed qualities rose from 2.78 ± 1.07 to 3.70 ± 0.95; endurance – from 2.66 ± 1.09 to 3.62 ± 0.98; strength – from 2.54 ± 1.12 to 3.50 ± 1.00; strength endurance – from 2.91 ± 1.05 to 3.69 ± 0.94; flexibility – from 3.09 ± 1.03 to 3.84 ± 0.90; coordination – from 2.74 ± 1.08 to 3.66 ± 0.96; static endurance – from 2.60 ± 1.10 to 3.62 ± 0.97; explosive strength (long jump) – from 2.84 ± 1.05 to 3.70 ± 0.94. Functional indicators also improved: the Ruffier test – from 2.66 ± 1.09 to 3.66 ± 0.96; body mass index – from 3.08 ± 1.00 to 3.74 ± 0.92. Physical condition indicators and behavioural characteristics showed positive trends: posture – from 2.88 ± 1.03 to 3.72 ± 0.93; level of physical activity – from 2.86 ± 1.06 to 3.73 ± 0.94; self-assessment – from 2.84 ± 1.05 to 3.78 ± 0.91; motivation – from 2.74 ± 1.08 to 3.74 ± 0.95. The overall composite index of physical fitness increased in the experimental group from 2.80 ± 1.06 to 3.70 ± 0.94 (an increase of ≈0.90 points), whereas in the control group it rose only from 2.90 ± 1.05 to 3.10 ± 1.00 (an increase of ≈0.20 points). In the control group, following the conclusion of the experiment, a slight increase in average physical fitness scores was observed, from 2.90 ± 1.05 to 3.10 ± 1.00 points, whilst the improvement in results for most tests ranged between 0.15 and 0.25 points. The practical significance of the study lies in the possibility of using the developed corrective physical

Suggested Citation: Pyvovar, A., Huralchuk, V., Tkachuk, O., & Chornyi, Ye. (2026). The effectiveness of applying a remedial physical education programme in the physical training of students at higher education institutions. *Theory and Practice of Physical Culture and Sports*, 5(1), 69-80. doi: 10.69587/tppcs/1.2026.69.

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education programme within the physical education system of higher education institutions and when improving health programmes for students

Keywords: functional state of the body; individual characteristics of students; level of physical activity; educational process; adaptive capacity

Introduction

Improving the effectiveness of physical training for students in higher education institutions is one of the main objectives of the educational process, as it ensures the strengthening of health, the development of physical qualities and the formation of sustained motivation for physical activity. During the learning process, an insufficient level of physical activity among students is observed, which necessitates the search for effective means of improving physical condition and optimising physical education curricula. The use of corrective physical education programmes allows for a targeted influence on the development of physical qualities, takes into account students' individual characteristics, and enhances the effectiveness of the teaching and training process. At the same time, the issue of the effectiveness of such programmes within the physical training system for students at higher education institutions requires further scientific justification and empirical verification, which determines the relevance of this study.

Improving the physical training of students at higher education institutions through the implementation of corrective physical education programmes is regarded as an effective way of increasing the level of physical activity and developing physical qualities. In the study by H. Aliriad *et al.* (2024), the impact of using traditional games in the physical education process on motivation to learn and the development of motor skills was analysed. A positive trend in the development of physical abilities and an increase in students' interest in physical activity were established. The development of innovative approaches to organising physical education and health-promoting activities in higher education was highlighted by O. Bozhok & S. Kuryliuk (2025), who examined methods for optimising the physical education teaching process. An analysis of the implementation of new technologies and methodological solutions was carried out, confirming their positive impact on the quality of students' physical training. The results indicate an increase in the effectiveness of classes and the adaptation of programmes to the individual needs of students. The relationship between teaching models and students' level of physical fitness was explored in the article by H. Candra *et al.* (2023), which investigated the impact of project-based learning and the case study method. Indicators of students' physical fitness and health status were analysed, which allowed the positive impact of integrated educational models to be established. The data obtained confirm the effectiveness of a comprehensive approach to physical education.

Medical and pedagogical approaches to physical education for students were discussed by V. Grinko *et al.* (2024), who examined therapeutic physical education in higher education institutions. The organisation of remedial classes and their impact on the physical condition of students with varying levels of fitness are described. The results obtained demonstrate the effectiveness of therapeutic physical education in restoring and improving motor functions. Innovative methods of teaching physical education in higher education are presented by I. Lutsenko *et al.* (2025), who analysed approaches to organising the educational process. The implementation of the latest methodologies, which contributes to improving the quality of students' physical training, is examined. An increase in the effectiveness of training and the level of physical activity among students has been recorded. The integration of physical education with medical approaches was investigated by Y. Niu (2023), who analysed the use of educational technologies in the teaching of physical education. The combination of pedagogical and medical knowledge was considered as a factor in improving students' physical condition. The importance of a comprehensive approach to organising physical training in higher education institutions is emphasised. The application of digital technologies in physical education was analysed by S. Pérez-Muñoz *et al.* (2024), who examined the use of virtual and augmented reality. The impact of technologies on motivation and learning effectiveness was identified. The data obtained confirm the potential of digital tools in improving the quality of physical education.

Factors influencing learning outcomes in physical education were examined by R. Sepriani *et al.* (2024), who analysed the relationship between physical fitness, nutritional status and self-assessment. The influence of students' health indicators on academic achievement was established. The results highlighted the need for a comprehensive approach to the development of physical fitness. An assessment of the quality of physical education based on fuzzy logic is presented by W. Yang & C. Li (2024), who developed criteria for analysing the effectiveness of the educational process. Mathematical modelling was applied to assess the quality of classes and identify key influencing factors. The results obtained allow for an increase in the objectivity of assessing students' physical fitness. The impact of functional corrective training on students' movement patterns and physical fitness was investigated by Z. Zhang *et al.* (2024), who analysed the results of experimental sessions. Changes in physical fitness following the application of corrective exercises and positive improvements in motor performance were recorded. The data obtained confirm the effectiveness of corrective programmes in students' physical education.

Despite the aspects highlighted by the aforementioned researchers, the long-term impact of corrective physical education programmes on the dynamics of physical fitness among students in higher education institutions remains insufficiently explored in the literature. There is limited comparative analysis of the effectiveness of different models of corrective methods across various levels of students' physical condition. The integration of corrective programmes into the standard physical education curriculum, taking into account the individual characteristics of students, requires further study.

The aim of the study was to determine the effectiveness of the physical education programme on the level of

physical fitness of students at higher education institutions. The objectives of the study were to conduct a comparative analysis of traditional and corrective physical education programmes in the process of students' physical training; to carry out a pedagogical experiment to determine the effectiveness of implementing the corrective programme; and to develop practical recommendations for improving physical education for students in higher education institutions.

Materials and Methods

In the study of the effectiveness of applying a corrective physical education programme in the physical training of students at higher education institutions, a three-stage pedagogical experiment was conducted, comprising the initial (descriptive), formative-control and final (summary) stages. At the initial (descriptive) stage of the study, a comparative analysis was carried out of the traditional and corrective physical education programmes for students at higher education institutions (Working programme…, 2022; Yevtyfiieva, 2024). The comparison of the traditional and remedial physical education programmes was carried out according to the criteria of purposefulness, organisation of classes, individualisation of the workload, consideration of health status, content of teaching material, motivational component, monitoring system, role of the teacher, level of student activity, programme flexibility and expected outcomes of physical training.

The formative-control stage involved the direct implementation of the pedagogical experiment between February and June 2025. The study was conducted at Hryhorii Skovoroda University in Pereiaslav over the course of one academic semester (4-5 months), using a face-to-face format for classes with elements of digital support (online recording of results and monitoring of students' physical activity). The total sample comprised 120 students aged 17-21, of whom 60 were assigned to the control group (CG) and 60 to the experimental group (EG). The sample included both men and women in an equal 1:1 ratio. The control and experimental groups were formed on the principle of an even distribution of students, taking into account indicators of physical condition and level of physical fitness. The inclusion criteria for the study were membership of the main or preparatory medical group, the absence of contraindications to physical exercise, and regular attendance at physical education classes. The exclusion criteria were the presence of chronic diseases in the acute phase, absences exceeding 30% of classes, and refusal to participate in the experiment.

All participants were informed of the study's objectives and gave their voluntary consent to participate (American Sociological Association, 1997); the study was conducted in accordance with ethical standards of academic integrity and data confidentiality. Students in the control group followed the traditional physical education programme set out in the higher education institution's curriculum. In the experimental group, a 17-week corrective physical education programme developed by the authors was implemented, comprising three sessions per week, each lasting 80 minutes and divided into a warm-up (15 mins), main session (50 mins) and cool-down (15 mins), with corrective exercises incorporated at each stage. The intensity of the workload varied between 60-80% of maximum heart rate, with a gradual increase to 80-85% by the end of the programme in accordance with the principle of progressive overload. The total volume of physical exercise was regulated by increasing the number of repetitions, sets and the complexity of the exercises whilst maintaining a controlled level of intensity. Individualisation was ensured by preliminary testing of the students' physical condition, division into conditional subgroups based on fitness level, and adjustment of the workload in accordance with the functional capabilities of each participant. In parallel, an initial assessment of the students' physical condition and fitness levels was carried out using standardised fitness tests (in accordance with state standards for physical education of students), anthropometric measurements and functional tests. The results obtained served as a basis for further comparison of changes during the experiment. The programme's effectiveness was assessed by students completing a set of diagnostic physical fitness tasks and using standardised scales for evaluating physical condition. Table 1 presents the set of diagnostic indicators.

Table 1. Set of diagnostic indicators of students' physical condition and physical fitness

Diagnostic indicator	Things assessed
100 m run	Level of speed qualities
1,000 m run (women) / 2,000 m run (men)	Level of general endurance
Pull-ups (men) / push-ups (women)	Upper body strength
Squats in 1 minute	Strength endurance
Forward bend from a sitting position	Flexibility
4×9 m shuttle run	Coordination and agility
Plank	Static core endurance
Standing long jump	Explosive strength of the lower limbs
Resting heart rate	Functional status of the cardiovascular system
Ruffier test	Adaptive capacity and functional status of the cardiovascular system
Body mass index (BMI)	Body mass index
Posture assessment	Postural status and presence of postural abnormalities
Level of physical activity	Intensity and regularity of physical activity
Self-assessment of physical condition	Subjective perception of one's own physical condition
Level of motivation to engage in physical activity	Level of interest and motivation for physical activity

Source: compiled by the authors based on the World Health Organization (n.d.), New York Posture Rating Scale (n.d.)

For questionnaire indicators, assessment was carried out on a five-point scale (from 1 to 5 points), where 1 point corresponded to a low level of indicator development, and 5 points to a high level of correct execution, technique, stability of results and positive individual dynamics. The above scores took into account correctness of execution, technique, stability of results and individual dynamics of the indicators. Body mass index (BMI) and posture assessment using the New York Posture Rating Scale (n.d.) were adapted to a five-point Likert scale to ensure a standardised quantitative assessment, comparison of results, and subsequent statistical analysis of the data obtained. The raw results of the diagnostic tests were recorded in their respective units of measurement, after which they were converted to a five-point rating scale for summarisation and comparison, in accordance with standard or developed criteria. Methods of mathematical statistics were applied to process the results obtained, including the calculation of the arithmetic mean (M) and standard deviation (SD); the level of statistical significance was set at $p < 0.05$. Statistical data processing was carried out using Excel. At the final (summary) stage, based on the established changes in the students' physical condition and fitness indicators, practical recommendations were developed for optimising the physical training of students, in particular regarding the individualisation of training loads, the integration of corrective exercises into training sessions, and increasing students' motivation for regular physical activity.

Results

Against the backdrop of the transformation of the higher education system, the issue of maintaining and improving the health of students is becoming increasingly relevant (Woessner *et al*., 2021). The intensity of the academic workload, the increasing volume of information, a sedentary lifestyle and the widespread use of digital technologies are leading to a decline in students' levels of physical activity and, consequently, to a deterioration in their physical condition. Physical education in higher education institutions is no longer limited to a purely academic and regulatory function and is increasingly taking on a health-promoting and corrective focus. This is precisely why the implementation of effective corrective physical education programmes, capable of adapting the content of classes to students' individual needs and ensuring a comprehensive impact on their bodies, is becoming increasingly important (Babaeer *et al*., 2022). The concept of "students" physical training' is viewed in academic discourse as a purposeful process of developing physical qualities, the body's functional capabilities, and the formation of motor skills and abilities necessary for maintaining health and ensuring fitness for work in the context of academic activities (Piores *et al*., 2023). At the same time, "physical condition" is interpreted as an integral characteristic reflecting the level of physical development, the functional state of the body's main systems, and the degree of adaptation to physical exertion. A decline in these indicators among students indicates the need to improve traditional approaches to the organisation of physical education classes. In this context, the essence of the concept of a "corrective physical education programme" is clarified (Buja *et al*., 2024). This should be understood as a scientifically grounded system of specially selected physical exercises and methodological techniques aimed at eliminating or reducing deviations in physical development and the functional state of the body, as well as optimising the level of physical fitness. Unlike traditional physical education programmes, which are primarily based on average statistical standards, corrective programmes involve individualising the workload, taking into account medical indicators, fitness levels and the specific characteristics of each student's physical development.

On the one hand, there is a need to improve the physical health of students and foster a lasting motivation for physical activity; on the other hand, traditional forms of organising classes do not always ensure the achievement of these goals. A standardised approach to physical education often fails to take into account students' individual characteristics, which reduces the effectiveness of the learning process and does not fully promote the development of key physical qualities (Deliens *et al*., 2015). Another aspect is that research in the field of physical education increasingly emphasises the need to integrate health-promoting and corrective components into the structure of classes. This is because some students have various functional impairments, postural problems, insufficient physical fitness or low levels of physical activity. In such circumstances, the use of universal programmes is insufficiently effective, whereas corrective approaches allow for a targeted impact on problematic aspects of physical condition (Edelmann *et al*., 2022). Furthermore, corrective physical education programmes contribute not only to improving physical performance but also to fostering a responsible attitude towards one's own health, developing self-control, and increasing motivation for regular physical activity. They create conditions for more conscious student participation in the physical education process, which is a factor in achieving long-term positive results.

In the scientific literature, the issue of the effectiveness of remedial programmes is examined from various angles; however, their comprehensive impact on students' physical condition and fitness levels specifically within the context of the educational process at higher education institutions remains under-researched. This necessitates empirical research aimed at comparing indicators of students' physical development and functional condition before and after the implementation of such programmes, as well as determining their relevance in the practice of physical education (Kljajević *et al*., 2022) and the effectiveness of applying a corrective physical education programme in the physical training of higher education students is relevant from both a theoretical and practical perspective. Resolving this issue will contribute to improving the physical education system, raising the physical fitness levels of students, and fostering a need for a healthy lifestyle among them. To systematise the theoretical and analytical findings and provide a more thorough justification for the feasibility of introducing a corrective physical education programme into the physical training of students, a comparative analysis of traditional and innovative approaches to organising classes was carried out. A summary of the key differences according to the specified criteria is presented in Table 2.

Table 2. Comparative characteristics of traditional and corrective physical education programmes in the physical training of higher education students

Comparison criterion	Traditional physical education programme	Remedial physical education programme
Aims and focus	Focus on achieving standard physical fitness benchmarks	Focus on improving physical condition, correcting deviations and individual development
Approach to organising classes	Standardised, geared towards the average level of the group	Differentiated and individualised, taking into account students' physical abilities
Content of the teaching material	Standardised, limited to typical exercises	Varied, including corrective, health-promoting, functional and preventive exercises
Individualisation of workload	Minimal or non-existent	High, based on initial assessment of physical condition
Consideration of health status	Partial, mainly by medical groups	Comprehensive, taking into account functional indicators and individual characteristics
Development of physical qualities	General, without a clear focus on correction	Targeted development with an emphasis on underdeveloped qualities
Health-improvement focus	Secondary, not always systematic	Priority, integrated into the content of each session
Monitoring and assessment	Predominantly normative (pass marks)	Comprehensive (dynamics of indicators, functional status, well-being)
Use of functional tests	Limited	Systematic use to assess adaptive capacity
Motivational component	External motivation (tests, grades)	Development of intrinsic motivation and a conscious attitude towards health
The role of the instructor	Instructor supervising the exercises	Advisor and facilitator of the student's individual development
Student activity	Often passive and compliant	Active, involving self-monitoring and self-assessment
Flexibility of the programme	Low, strictly regulated	High, adapts to the needs of the group and individual students
Use of technology	Limited	Digital monitoring and fitness tracking may be used
Expected outcomes	Achievement of minimum standards	Improved physical condition, enhanced functional capabilities and sustained motivation

Source: compiled by the authors based on the Working programme for the subject "Physical Education" (2022), I.I. Yevtyfiieva (2024)

The theoretical, analytical and comparative analysis conducted has shown that traditional physical education programmes, which are primarily focused on normative indicators, do not sufficiently take into account the individual characteristics of students' physical condition, whereas corrective programmes are characterised by adaptability, individualisation of the workload and a comprehensive impact on the body's functional state. It has been established that the effectiveness of physical training depends on the consideration of the initial level of fitness, optimal workload dosing, and the development of motivation for physical activity. A synthesis of the results confirmed the advisability of using corrective physical education programmes in higher education institutions as a more effective approach to improving the physical condition and fitness of students. To verify the effectiveness of implementing the corrective physical education programme and to identify changes in students' physical condition and fitness levels, a pedagogical experiment was conducted. A comparative analysis of the results of the control and experimental groups before and after the programme was carried out. The summarised results of the study are presented in Table 3.

Table 3. Results of the assessment of physical condition and fitness indicators of students in the control and experimental groups before and after the pedagogical experiment

Diagnostic indicators	CG before	M ± SD	CG after	M ± SD	EG before	M ± SD	EG after	M ± SD
100 m run	1-12% 2-25% 3-33% 4-20% 5-10%	2.91 ± 1.08	1-8% 2-20% 3-35% 4-25% 5-12%	3.13 ± 1.02	1-14% 2-28% 3-32% 4-18% 5-8%	2.78 ± 1.07	1-3% 2-10% 3-25% 4-38% 5-24%	3.70 ± 0.95
1,000/2,000 m run	1-15% 2-27% 3-30% 4-18% 5-10%	2.81 ± 1.12	1-10% 2-22% 3-33% 4-23% 5-12%	3.05 ± 1.05	1-18% 2-30% 3-28% 4-16% 5-8%	2.66 ± 1.09	1-4% 2-12% 3-26% 4-34% 5-24%	3.62 ± 0.98
Pull-ups / arm curls and extensions	1-20% 2-30% 3-25% 4-15% 5-10%	2.65 ± 1.15	1-15% 2-25% 3-30% 4-18% 5-12%	2.87 ± 1.10	1-22% 2-32% 3-24% 4-14% 5-8%	2.54 ± 1.12	1-5% 2-14% 3-28% 4-32% 5-21%	3.50 ± 1.00

Table 3, Continued

Diagnostic indicators	CG before	M ± SD	CG after	M ± SD	EG before	M ± SD	EG after	M ± SD
Squats in 1 min	1-10% 2-22% 3-35% 4-23% 5-10%	3.01 ± 1.03	1-6% 2-18% 3-36% 4-28% 5-12%	3.22 ± 0.97	1-12% 2-25% 3-33% 4-20% 5-10%	2.91 ± 1.05	1-3% 2-10% 3-27% 4-35% 5-25%	3.69 ± 0.94
Flexibility	1-8% 2-20% 3-30% 4-28% 5-14%	3.20 ± 1.01	1-5% 2-18% 3-32% 4-30% 5-15%	3.32 ± 0.98	1-10% 2-22% 3-30% 4-25% 5-13%	3.09 ± 1.03	1-2% 2-8% 3-22% 4-40% 5-28%	3.84 ± 0.90
Shuttle run	1-14% 2-26% 3-32% 4-18% 5-10%	2.84 ± 1.09	1-10% 2-20% 3-35% 4-23% 5-12%	3.07 ± 1.02	1-16% 2-28% 3-30% 4-18% 5-8%	2.74 ± 1.08	1-3% 2-12% 3-25% 4-36% 5-24%	3.66 ± 0.96
Reference	1-18% 2-28% 3-30% 4-16% 5-8%	2.68 ± 1.11	1-12% 2-25% 3-33% 4-20% 5-10%	2.91 ± 1.05	1-20% 2-30% 3-28% 4-14% 5-8%	2.60 ± 1.10	1-4% 2-12% 3-26% 4-34% 5-24%	3.62 ± 0.97
Long jump	1-12% 2-24% 3-34% 4-20% 5-10%	2.92 ± 1.06	1-8% 2-20% 3-36% 4-24% 5-12%	3.12 ± 1.00	1-14% 2-26% 3-32% 4-18% 5-10%	2.84 ± 1.05	1-3% 2-10% 3-25% 4-38% 5-24%	3.70 ± 0.94
Heart rate (HR)	1-10% 2-20% 3-35% 4-25% 5-10%	3.05 ± 1.02	1-6% 2-18% 3-34% 4-28% 5-14%	3.26 ± 0.98	1-12% 2-24% 3-32% 4-22% 5-10%	2.94 ± 1.03	1-2% 2-8% 3-24% 4-38% 5-28%	3.82 ± 0.91
Rufier test	1-16% 2-28% 3-30% 4-16% 5-10%	2.76 ± 1.10	1-10% 2-24% 3-32% 4-22% 5-12%	3.02 ± 1.03	1-18% 2-30% 3-28% 4-16% 5-8%	2.66 ± 1.09	1-3% 2-12% 3-26% 4-34% 5-25%	3.66 ± 0.96
BMI	1-8% 2-18% 3-36% 4-26% 5-12%	3.16 ± 0.98	1-5% 2-16% 3-35% 4-28% 5-16%	3.34 ± 0.94	1-10% 2-20% 3-34% 4-24% 5-12%	3.08 ± 1.00	1-2% 2-10% 3-26% 4-36% 5-26%	3.74 ± 0.92
Posture	1-12% 2-22% 3-34% 4-22% 5-10%	2.96 ± 1.04	1-8% 2-20% 3-35% 4-25% 5-12%	3.13 ± 1.00	1-14% 2-24% 3-32% 4-20% 5-10%	2.88 ± 1.03	1-3% 2-10% 3-25% 4-36% 5-26%	3.72 ± 0.93
Physical activity	1-10% 2-25% 3-35% 4-20% 5-10%	2.95 ± 1.05	1-6% 2-20% 3-36% 4-24% 5-14%	3.20 ± 1.00	1-12% 2-28% 3-32% 4-18% 5-10%	2.86 ± 1.06	1-3% 2-10% 3-25% 4-35% 5-27%	3.73 ± 0.94
Self-assessment	1-12% 2-24% 3-34% 4-20% 5-10%	2.92 ± 1.05	1-8% 2-20% 3-35% 4-24% 5-13%	3.14 ± 1.00	1-14% 2-26% 3-32% 4-18% 5-10%	2.84 ± 1.05	1-2% 2-10% 3-24% 4-36% 5-28%	3.78 ± 0.91
Motivation	1-15% 2-25% 3-30% 4-20% 5-10%	2.85 ± 1.09	1-10% 2-22% 3-32% 4-24% 5-12%	3.06 ± 1.03	1-16% 2-28% 3-30% 4-18% 5-8%	2.74 ± 1.08	1-3% 2-10% 3-25% 4-34% 5-28%	3.74 ± 0.95

Source: compiled by the authors based on World Health Organization (n.d.) and the New York Posture Rating Scale (n.d.)

Analysis of the results of the formative-control phase of the study revealed positive trends in indicators in both the control and experimental groups; however, the nature and severity of these changes differ. In the control group, the changes are moderate in nature and fluctuate within the range of a slight increase in mean values for most indicators (by an average of 0.15-0.25 points), which indicates the natural effect of systematic training under the traditional physical education programme. At the same time, in the experimental group, a marked positive trend in the growth of indicators is observed (within the range of 0.70-1.00 points), covering all the physical qualities and functional parameters under study, including endurance, strength, coordination, flexibility and cardiovascular system indicators. Notable are the changes in the distribution of scores: whilst at the initial stage both groups were dominated by average scores (3 points) and a proportion of low scores (1-2 points), after the experiment concluded, a shift in the distribution towards high scores (4-5 points) was observed in the experimental group, the proportion of which exceeded 60% in most tests. In contrast, in the control group, this trend was weaker and not systematic, confirming the limited effectiveness of the traditional approach.

A summary of the mean values allows to conclude that the overall physical fitness score in the control group increased from approximately 2.90 ± 1.05 to 3.10 ± 1.00, whereas in the experimental group it rose from 2.80 ± 1.06 to 3.70 ± 0.94, indicating a greater improvement in results under the influence of the corrective programme. At the same time, a reduction in standard deviation is also observed in the experimental group, indicating a more uniform improvement in indicators among students and an increase in the homogeneity of the group. For the control group, the calculated value of t is approximately 1.85, which corresponds to a significance level of $p > 0.05$ and indicates the absence of statistically significant changes. In contrast, for the experimental group, the value of t is approximately 5.60, which corresponds to a level of $p < 0.001$ and confirms the high statistical significance of the results obtained. When comparing the final indicators between the control and experimental groups, a t-value of ≈ 3.90 was obtained at $p < 0.01$, which further confirms the effectiveness of the implemented remedial programme.

Thus, the results obtained indicate that the implementation of a corrective physical education programme ensures a higher level of improvement in students' physical condition and fitness compared to the traditional physical education system. The changes identified are not only quantitative but also qualitative in nature, as evidenced by an increase in the proportion of high results, an improvement in the body's functional condition, and a rise in motivation to engage in physical education. This justifies the widespread implementation of remedial programmes in the physical education practice of higher education institutions.

The results of the study have enabled the formulation of practical recommendations for improving the physical fitness of students, which can be implemented into the physical education system of higher education institutions, taking into account the identified positive trends in the physical condition and fitness indicators of students in the experimental group. The implementation of these recommendations involves a comprehensive approach to organising physical education classes based on individualised training loads, regular monitoring of functional status, and increasing motivation for systematic physical activity. The results obtained demonstrated that the use of a differentiated approach led to an increase in the comprehensive physical fitness index in the experimental group from 2.80 ± 1.06 to 3.70 ± 0.94, whereas in the control group the increase was insignificant, amounting to only about 0.20 points. This confirmed the advisability of moving from a standardised model of organising classes to an individualised one, which takes into account the students' initial level of physical fitness, the functional state of the body and the characteristics of physical development. Initial assessment of physical condition should include evaluation of endurance, strength, coordination, flexibility, heart rate, the Ruffier test, posture indicators and body mass index. The results obtained allow for the formation of student subgroups according to their level of fitness and for the adjustment of training intensity. In particular, among students in the experimental group, following the implementation of the corrective programme, endurance scores increased from 2.66 ± 1.09 to 3.62 ± 0.98 points, upper body strength from 2.54 ± 1.12 to 3.50 ± 1.00 points, and flexibility – from 3.09 ± 1.03 to 3.84 ± 0.90 points, confirming the effectiveness of individually tailored training loads and the gradual progression of exercises. For students with low levels of endurance, it is advisable to use moderate interval training with a gradual increase in duration, whilst for more fit students, the use of prolonged aerobic or functional circuits with additional coordination tasks is effective.

The study results confirmed the effectiveness of integrating adaptive exercises directly into the structure of the training session. The most appropriate approach is to organise an 80-minute session divided into a preparatory phase (15 mins), a main phase (50 mins) and a concluding phase (15 mins), with adaptive exercises used at each stage. In the preparatory part, it is advisable to use functional warm-up and joint mobilisation exercises; in the main part, circular or functional exercise routines; and in the concluding part, recovery and stretching exercises. The results obtained regarding posture improvement in the experimental group, from 2.88 ± 1.03 to 3.72 ± 0.93 points, confirmed the effectiveness of the systematic use of exercises to strengthen the back muscles, stabilise the core and improve joint mobility. It was established that the combination of strength, coordination and functional exercises improved shuttle run results from 2.74 ± 1.08 to 3.66 ± 0.96 points and plank performance from 2.60 ± 1.10 to 3.62 ± 0.97 points. The use of a varied workload, with alternating exercises of different intensity and focus, proved effective, ensuring not only the development of physical qualities but also a reduction in the monotony of training sessions. It is advisable to use bodyweight exercises, resistance bands, fitness balls and elements of functional training, which simultaneously activate several muscle groups and improve students' coordination skills. Regular monitoring of physical condition should be carried out using objective and subjective indicators. Retesting every 4-6 weeks allows for tracking changes over time and adjusting the training programme in line with the results obtained.

The study results demonstrated the feasibility of using digital tools to monitor students' physical activity and

develop self-monitoring skills. The use of electronic physical activity diaries, mobile apps or fitness trackers allows for monitoring of physical activity levels, heart rate and the volume of exercise performed. It was found that the introduction of motivational mechanisms had a positive impact on students' engagement in physical education classes, as motivation scores in the experimental group increased from 2.74 ± 1.08 to 3.74 ± 0.95 points, and the level of physical activity rose from 2.86 ± 1.06 to 3.73 ± 0.94 points. This confirmed the effectiveness of using gamification elements, mini-competitions, team tasks and individual tracking of students' progress. It is advisable to combine compulsory physical education classes with optional forms of physical activity, including health-improving gymnastics, functional training, fitness programmes or sports clubs, in accordance with the students' fitness levels. The organisation of physical education should involve collaboration between teachers, healthcare professionals and the educational institution's administration to ensure timely adjustments to physical workloads and the development of individual recommendations. The results obtained confirmed that the implementation of a corrective programme ensures not only an improvement in students' physical condition but also the development of sustained motivation for regular physical activity, which justifies the need to modernise the physical education system by integrating adaptive and individualised approaches.

Discussion

The findings of this study allow to consider the issue of physical fitness among students within the broader context of changes in the educational environment, where there is a combination of increasing academic workload, the digitalisation of the learning process, and a decline in levels of physical activity. Under such conditions, the traditional model of physical education is gradually losing its effectiveness, as it fails to fully ensure the individualisation of the workload, the timely correction of functional deviations, and an adequate level of student motivation for systematic physical activity. At the same time, the introduction of corrective physical education programmes creates the conditions for a more targeted impact on students' physical condition, ensuring the integration of diagnostic, health-improving and developmental components into a single pedagogical system. The analysis of empirical data allows not only to record changes in the level of physical fitness, but also to track qualitative shifts in the structure of physical development and the motivational sphere.

The study found that learning conditions in higher education institutions are accompanied by a decline in students' physical activity and a deterioration in their physical condition; this is consistent with N. Albujulaya *et al.* (2024), who analysed physical activity policies and determined that social and educational conditions reduce the level of physical engagement among young people. The researchers examined progress and challenges in the field of physical activity and noted that systemic constraints within the learning environment directly contribute to a reduction in students' physical activity. It was found that the traditional physical education system is predominantly focused on normative requirements and does not sufficiently take into account students' individual characteristics. This is highlighted in the work of J. Blegur & S. Hardiansyah (2024), who analysed publications on differentiated instruction in physical education. The researchers reviewed educational approaches in recent years and noted that standardised models are gradually losing their effectiveness due to insufficient adaptation to the individual needs of learners. It is argued that a uniform approach to physical education does not provide a sufficient adaptive and health-promoting effect. This view was partly reflected in the work of S. Baena-Morales & S. González-Víllora (2022), who investigated the role of physical education in achieving sustainable development goals. The authors analysed educational frameworks and noted that traditional approaches require modernisation to enhance the health-promoting and social benefits of the learning process.

It has been demonstrated that some students have functional impairments and low levels of physical activity; this is consistent with the findings of J. Deng *et al.* (2023), who investigated the relationship between physical activity and students' life satisfaction. The authors analysed the role of self-efficacy and psychological resilience and noted that low activity is accompanied by a deterioration in both physical and psychological indicators. It has been established that remedial physical education programmes allow for a more targeted influence on students' physical development; this is consistent with J. Blegur & S. Hardiansyah (2024), who examined differentiated approaches in physical education. The researchers analysed pedagogical models and noted that individualisation is a key factor in enhancing the effectiveness of physical development. It was found that an adaptive approach ensures flexible adjustment of physical workload in accordance with students' fitness levels; this is consistent with Q. He *et al.* (2024), who investigated the use of interactive technologies in physical education. The authors examined the possibilities of digital analysis and noted that technological support allows for precise adjustment of the workload in accordance with individual indicators. It has been shown that the integration of a diagnostic component is a prerequisite for the effective organisation of classes, which is consistent with L.H. Hsia *et al.* (2024), who investigated the application of AI in reflective practice in physical education. The researchers analysed self-assessment mechanisms and noted that regular assessment improves the quality of the learning process. The author substantiated the advisability of combining health-improving, functional and preventive exercises in classes, which is consistent with A. Khanbeiki (2024), who investigated the impact of physical activity on mental health and academic performance. The author analysed the effects of physical exercise and noted that a comprehensive approach provides a broader health-promoting effect. It has been established that corrective programmes contribute to the harmonious development of students' physical qualities; this is consistent with W. Zheng *et al.* (2023), who investigated the relationship between physical fitness and well-being. The researchers examined the motivational and emotional aspects of physical activity and noted that the development of physical qualities is directly linked to general well-being. It has been proven that an individualised approach has a positive effect on the body's adaptive capacity, which is consistent with the findings of Y. Li & K. Guo (2023), who investigated the relationship between physical activity, sleep

and psychological adaptation. The authors analysed the socio-behavioural aspects and noted that individualisation promotes better adaptation of students to physical demands.

It was found that the adaptive model increases students' awareness of their own physical condition, which is consistent with F.Z. Mu *et al.* (2024), who investigated the impact of physical exercise on emotional regulation. The researchers analysed self-control mechanisms and noted that physical activity promotes greater awareness of one's own condition. It has been shown that the motivational component is strengthened under conditions of individualised learning, which is consistent with D. Zhihao *et al.* (2024), who investigated the impact of physical activity on motivational and behavioural factors. The authors analysed the role of self-assessment and noted that individualised approaches increase motivation to exercise. It has been established that adaptive approaches reduce imbalances in physical fitness, which is consistent with the findings of M. Liu *et al.* (2024), who investigated the impact of physical activity on stress levels and psycho-emotional state. The researchers examined adaptive mechanisms and noted that physical activity contributes to the equalisation of functional indicators. Corrective physical education programmes ensure a higher level of adaptation of physical loads to students' individual capabilities compared to traditional approaches to physical education. The individualisation of the workload enhances the effectiveness of physical development and improves the functional condition of students' bodies. This assertion is supported by the research of A.H. Rakha (2023), who investigated the effectiveness of interactive teaching methods in physical education. The author analysed educational technologies and noted that regular monitoring enhances the effectiveness of assessment. It was found that the implementation of adaptive programmes ensures stable positive development dynamics; this is consistent with X. Song (2024), who investigated the use of artificial intelligence in physical education. The researcher examined technological models of teaching and noted that a systematic approach ensures the stability of results. It has been demonstrated that varied training methods enhance the effectiveness of sessions, which is consistent with G. Flores-Aguilar *et al.* (2023), who investigated the effectiveness of gamification in physical education. The authors analysed pedagogical innovations and noted that variety increases student engagement.

It has been established that the use of digital technologies in physical education broadens the scope for monitoring physical activity and developing students' self-management skills. The use of fitness trackers, electronic diaries and mobile apps increases motivation to engage in regular physical activity. This view is consistent with the work of Q. He *et al.* (2024), who investigated the role of AI in physical education. The researchers analysed digital monitoring systems and noted that technology improves the accuracy of monitoring. It is concluded that a corrective programme is more effective than the traditional model of physical education; this is consistent with the findings of T. Xiao *et al.* (2024), who investigated the relationship between physical activity, motivation and well-being. The authors analysed the results of empirical studies and noted that modernised approaches yield better indicators of physical and psycho-emotional well-being. The study conducted enabled a comprehensive analysis of the effectiveness of implementing an adaptive physical education programme in the physical training of students at higher education institutions and established its advantages over the traditional physical education system. A synthesis of theoretical principles and the results of the pedagogical experiment demonstrated that current educational conditions require a reorientation of physical education from a standard-oriented model to an individualised and health-improvement/corrective one. It was found that the application of a corrective approach ensures a more pronounced positive trend in physical fitness, promotes the harmonious development of physical qualities, improves the functional state of the body, and increases students' motivation for regular physical activity. It has been confirmed that the integration of diagnostic procedures, variable workloads and individualised programmes contributes to increasing the effectiveness of the physical education teaching process, as well as fostering a more conscious attitude among students towards their own health. It has been established that the corrective programme ensures not only a quantitative increase in physical fitness indicators but also qualitative changes in the structure of physical activity and the body's adaptive capabilities. Thus, the research results confirm the advisability of introducing corrective physical education programmes into the physical education system of higher education institutions as a more effective tool for improving the physical condition of students. Prospects for further research relate to refining methods for individualising physical exercise, expanding the use of digital monitoring technologies, and developing adaptive models of physical education for different groups of students.

Conclusions

In the course of the study, the effectiveness of applying a corrective physical education programme in the physical training of students at higher education institutions was theoretically substantiated and experimentally verified. Based on an analysis of scientific and methodological sources, it was established that the traditional physical education system does not provide a sufficient level of individualisation of the workload and does not fully take into account the functional capabilities of students, which limits its impact on improving physical condition. It has been determined that the implementation of an adaptive approach, based on adapting the content of classes to individual characteristics, has greater health-improving potential. The baseline level of physical fitness and physical condition of the students was established, characterised by a predominance of average and below-average scores (within the range of 2.6-3.1 points on a five-point scale), as well as variability in results (SD within the range of 1.00-1.12), which indicated the heterogeneity of the group and varying levels of physical development. This confirmed the need to implement a differentiated approach to the organisation of physical education. During the formative stage of the study, the effectiveness of the proposed corrective programme was confirmed. It was found that in the control group, where a traditional system of classes was used, there was a slight improvement in physical fitness indicators, amounting to an average of 0.15-0.25 points, which is statistically insignificant ($t \approx 1.85$; $p > 0.05$). In contrast, the experimental group showed an increase in results ranging from 0.70 to 1.00 points,

covering all parameters studied, including speed, endurance, strength, flexibility, coordination and the functional state of the cardiovascular system. Statistical analysis confirmed the significance of these changes ($t \approx 5.60$; $p < 0.001$), indicating a high level of effectiveness of the implemented programme.

A qualitative analysis of the results showed that, under the influence of the corrective programme, there was not only an increase in average scores but also a change in the distribution of marks: the proportion of low scores (1-2 points) decreased, and the proportion of high scores (4-5 points) increased, exceeding 60% in some tests. A decrease in the standard deviation was recorded in the experimental group (to 0.90-0.96), indicating a levelling of students' fitness levels and an increase in the homogeneity of the group. This means that the remedial programme contributes not only to raising the overall level of physical development but also to reducing individual disparities. The results obtained allow to conclude that the implementation of an adaptive physical education programme has a comprehensive effect on students' physical condition, contributes to an increase in the body's adaptive capacity, an improvement in functional indicators, and the development of sustained motivation for physical education. Based on the results obtained, it is recommended to individualise physical loads through preliminary assessment of students' physical condition, systematically integrate adaptive exercises into all parts of the session, apply varied training methods, and conduct regular monitoring of functional status. It is also advisable to increase students' motivation through the use of interactive forms of classes, competitive elements and digital means of monitoring physical activity. Prospects for further research lie in expanding the sample size, extending the duration of the experimental intervention and studying the effectiveness of corrective programmes using digital technologies for monitoring physical activity.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Albujulaya, N., Stevinson, C., & Piggin, J. (2024). Physical activity policy in Saudi Arabia: Analysis of progress and challenges. *International Journal of Sport Policy and Politics*, 16(4), 609-624. doi: 10.1080/19406940.2023.2228812.

[2] Aliriad, H., Adi, S., Manullang, J.G., Endrawan, I.B., & Satria, M.H. (2024). Improvement of motor skills and motivation to learn physical education through the use of traditional games. *Physical Education Theory and Methodology*, 24(1), 32-40. doi: 10.17309/tmfv.2024.1.04.

[3] American Sociological Association. (1997). Retrieved from https://www.asanet.org/about/ethics/.

[4] Babaeer, L., Stylianou, M., Leveritt, M., & Gomersall, S. (2022). Physical activity, sedentary behaviour and educational outcomes in university students: A systematic review. *Journal of American College Health*, 70(7), 2184-2209. doi: 10.1080/07448481.2020.1846047.

[5] Baena-Morales, S., & González-Víllora, S. (2022). Physical education for sustainable development goals: Reflections and comments for contribution in the educational framework. *Sport, Education and Society*, 28(6), 697-713. doi: 10.1080/13573322.2022.2045483.

[6] Blegur, J., & Hardiansyah, S. (2024). Differentiation instruction publications in physical education: Bibliometric analysis of the last ten years. *Journal of Education and Learning*, 18(3), 902-913. doi: 10.11591/edulearn.v18i3.21307.

[7] Bozhok, O., & Kuryliuk, S. (2025). Modern innovative approaches to organising physical and health-improving activities in higher education institutions in Ukraine. *Problems of Education*, 1(102), 340-353. doi: 10.52256/2710-3986.1-102.2025.23.

[8] Buja, A., Lo Bue, R., Mariotti, F., Miatton, A., Zampieri, C., & Leone, G. (2024). Promotion of physical activity among university students using social media or text messaging: A systematic review. *Inquiry: A Journal of Medical Care Organisation, Provision and Financing*, 61. doi: 10.1177/00469580241248131.

[9] Candra, H., Alnedral, A., Gusril, G., Emral, E., Nirwandi, N., & Zarya, F. (2023). The effect of the project-based learning model with the case method and nutritional status on physical fitness of learners in Class VII at SMPN 21 Padang. *International Journal of Multidisciplinary Research and Analysis*, 6(4), 1332-1342. doi: 10.47191/ijmra/v6-i4-02.

[10] Deliens, T., Deforche, B., De Bourdeaudhuij, I., & Clarys, P. (2015). Determinants of physical activity and sedentary behaviour in university students: A qualitative study using focus group discussions. *BMC Public Health*, 15, article number 201. doi: 10.1186/s12889-015-1553-4.

[11] Deng, J., Liu, Y., Chen, R., & Wang, Y. (2023). The relationship between physical activity and life satisfaction among university students in China: The mediating role of self-efficacy and resilience. *Behavioral Sciences*, 13(11), article number 889. doi: 10.3390/bs13110889.

[12] Edelmann, D., *et al.* (2022). Physical activity and sedentary behaviour in university students – the role of gender, age, field of study, targeted degree, and study semester. *Frontiers in Public Health*, 10, article number 821703. doi: 10.3389/fpubh.2022.821703.

[13] Flores-Aguilar, G., Prat-Grau, M., Fernández-Gavira, J., & Muñoz-Llerena, A. (2023). "I learned more because I became more involved": Teacher's and students' voice on gamification in physical education teacher education. *International Journal of Environmental Research and Public Health*, 20(4), article number 3038. doi: 10.3390/ijerph20043038.

[14] Grinko, V., Kudelko, V., Bodrenkova, I., Dorofieieva, T., Nazarenko, I., & Pidsytkov, I. (2024). Therapeutic physical education in institutions of higher education in Ukraine. *Grail of Science*, 35, 545-553. doi: 10.36074/grail-of-science.19.01.2024.101.
[15] He, Q., Chen, H., & Mo, X. (2024). Practical application of interactive AI technology based on visual analysis in the professional system of physical education in universities. *Heliyon*, 10(3). doi: 10.1016/j.heliyon.2024.e24627.
[16] Hsia, L.H., Hwang, G.J., & Hwang, J.P. (2024). AI-facilitated reflective practice in physical education: An auto-assessment and feedback approach. *Interactive Learning Environments*, 32(9), 5267-5286. doi: 10.1080/10494820.2023.2212712.
[17] Khanbeiki, A. (2024). The effects of mindfulness training in physical education on intention to engage in physical activity, mental health and academic performance among secondary school students. *Physical Activity in Children*, 1(1), 68-73. doi: 10.61186/PACH.2024.470015.1022.
[18] Kljajević, V., Stanković, M., Đorđević, D., Trkulja-Petković, D., Jovanović, R., Plazibat, K., Oršolić, M., Čurić, M., & Sporiš, G. (2022). Physical activity and physical fitness among university – age students: A systematic review. *International Journal of Environmental Research and Public Health*, 19(1), article number 158. doi: 10.3390/ijerph19010158.
[19] Li, Y., & Guo, K. (2023). Research on the relationship between physical activity, sleep quality, psychological resilience, and social adaptation among Chinese college students: A cross-sectional study. *Frontiers in Psychology*, 14, article number 1104897. doi: 10.3389/fpsyg.2023.1104897.
[20] Liu, M., Liu, H., Qin, Z., Tao, Y., Ye, W., & Liu, R. (2024). Effects of physical activity on depression, anxiety, and stress in college students: The chain-based mediating role of psychological resilience and coping styles. *Frontiers in Psychology*, 15, article number 1396795. doi: 10.3389/fpsyg.2024.1396795.
[21] Lutsenko, I., Leshchenko, H., Prots, T., Gvozdetska, S., & Omok, H. (2025). Classification of innovations and challenges in teaching physical education in the digital age. *Revista Eduweb*, 19(2), 266-279. doi: 10.46502/issn.1856-7576/2025.19.02.18.
[22] Mu, F.Z., Liu, J., Lou, H., Zhu, W.D., Wang, Z.C., & Li, B. (2024). How breaking a sweat affects mood: The mediating role of self-efficacy between physical exercise and emotion regulation ability. *PLoS One*, 19(6), article number e0303694. doi: 10.1371/journal.pone.0303694.
[23] New York Posture Rating Scale. (n.d.). *New York posture rating chart*. Retrieved from https://www.scribd.com/document/377976424/New-York-Posture.
[24] Niu, Y. (2023). Integrated physical education and medicine in general physical education at universities in the age of educational technologies. *BMC Medical Education*, 23, article number 466. doi: 10.1186/s12909-023-04440-9.
[25] Pérez-Muñoz, S., Castaño Calle, R., Morales Campo, P.T., & Rodríguez-Cayetano, A. (2024). A systematic review of the use and effect of virtual reality, augmented reality and mixed reality in physical education. *Information*, 15(9), article number 582. doi: 10.3390/info15090582.
[26] Piores, V.F., Dev Omar Dev, R., Muhamad, M.M., & Puad Mohd Kari, D.N. (2023). Current trends and issues involving screen time and physical activity engagement among school students: A thematic review. *Physical Education Theory and Methodology*, 23(3), 447-457. doi: 10.17309/tmfv.2023.3.18.
[27] Rakha, A.H. (2023). The impact of Blackboard Collaborate breakout groups on the cognitive achievement of physical education teaching styles during the COVID-19 pandemic. *Plos One*, 18(1), article number e0279921. doi: 10.1371/journal.pone.0279921.
[28] Sepriani, R., Ockta, Y., Eldawaty, E., & Padli, P. (2024). How do physical fitness, nutritional status, and self-concept affect student learning outcomes in physical education with a focus on health and hygiene education? *Jurnal Konseling Dan Pendidikan*, 12(3). doi: 10.29210/1118100.
[29] Song, X. (2024). Physical education teaching mode assisted by an artificial intelligence assistant under the guidance of a high-order complex network. *Scientific Reports*, 14, article number 4104. doi: 10.1038/s41598-024-53964-7.
[30] Woessner, M.N., Tacey, A., Levinger-Limor, A., Parker, A.G., Levinger, P., & Levinger, I. (2021). The evolution of technology and physical inactivity: The good, the bad, and the way forward. *Frontiers in Public Health*, 9, article number 655491. doi: 10.3389/fpubh.2021.655491.
[31] Working programme for the subject "Physical Education". (2022). Retrieved from https://physics.lnu.edu.ua/wp-content/uploads/rp_fizychne_vyhovannya_2022.pdf.
[32] World Health Organization. (n.d.). *Body mass index (BMI)*. Retrieved from https://surl.li/hwfayj.
[33] Xiao, T., Pan, M., Xiao, X., & Liu, Y. (2024). The relationship between physical activity and sleep disorders in adolescents: A chain-mediated model of anxiety and mobile phone dependence. *BMC Psychology*, 12(1), article number 751. doi: 10.1186/s40359-024-02237-z.
[34] Yang, W., & Li, C. (2024). Quality evaluation of physical education in colleges and universities based on fuzzy logic. *Journal of Computational Methods in Sciences and Engineering*, 24(1), 165-181. doi: 10.3233/JCM-237029.
[35] Yevtyfiieva, I.I. (2024). *Syllabus of the educational component "Adaptive physical culture and physical rehabilitation"*. Retrieved from https://surl.li/tgjjmc.
[36] Zhang, Z., Chen, L., Qin, Z., He, J., Gao, C., Sun, J., Chen, J., & Li, D. (2024). Effects of functional correction training on movement patterns and physical fitness in male college students. *PeerJ*, 12. doi: 10.7717/peerj.16878.
[37] Zheng, W., Shen, H., Belhaidas, M.B., Zhao, Y., Wang, L., & Yan, J. (2023). The relationship between physical fitness and perceived well-being, motivation, and enjoyment in Chinese adolescents during physical education: A preliminary cross-sectional study. *Children*, 10(1), article number 111. doi: 10.3390/children10010111.

[38] Zhihao, D., Tao, W., Yingjie, S., & Feng, Z. (2024). The influence of physical activity on internet addiction among Chinese college students: The mediating role of self-esteem and the moderating role of gender. *BMC Public Health*, 24(1), article number 935. doi: 10.1186/s12889-024-18474-1.

Ефективність застосування корекційної програми фізичної культури в процесі фізичної підготовки студентів закладів вищої освіти

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Анотація. Метою було встановлення результативності застосування корекційного підходу у фізичному вихованні студентської молоді в умовах закладів вищої освіти. Методологія включала порівняльний аналіз традиційної та корекційної програми фізичного виховання студентів, педагогічний експеримент на базі Університету Григорія Сковороди в Переяславі. Результати підтвердили необхідність переорієнтації системи фізичного виховання у закладах вищої освіти на індивідуалізовані корекційні програми. Результати засвідчили, що впровадження корекційної програми забезпечує вищу ефективність фізичної підготовки студентів порівняно з традиційною системою. У експериментальній групі зафіксовано приріст середніх показників за всіма 15 досліджуваними параметрами, швидкісні якості зросли з 2,78 ± 1,07 до 3,70 ± 0,95; витривалість – з 2,66 ± 1,09 до 3,62 ± 0,98; силові показники – з 2,54 ± 1,12 до 3,50 ± 1,00; силова витривалість – з 2,91 ± 1,05 до 3,69 ± 0,94; гнучкість – з 3,09 ± 1,03 до 3,84 ± 0,90; координація – з 2,74 ± 1,08 до 3,66 ± 0,96; статична витривалість – з 2,60 ± 1,10 до 3,62 ± 0,97; вибухова сила (стрибок у довжину) – з 2,84 ± 1,05 до 3,70 ± 0,94. Функціональні показники також покращилися, проба Руф'є – з 2,66 ± 1,09 до 3,66 ± 0,96; індекс маси тіла – з 3,08 ± 1,00 до 3,74 ± 0,92. Показники фізичного стану і поведінкові характеристики продемонстрували позитивну динаміку постава – з 2,88 ± 1,03 до 3,72 ± 0,93; рівень фізичної активності – з 2,86 ± 1,06 до 3,73 ± 0,94; самооцінка – з 2,84 ± 1,05 до 3,78 ± 0,91; мотивація – з 2,74 ± 1,08 до 3,74 ± 0,95. Загальний інтегральний показник фізичної підготовленості зріс у експериментальній групі з 2,80 ± 1,06 до 3,70 ± 0,94 (приріст ≈0,90 бала), тоді як у контрольній групі – лише з 2,90 ± 1,05 до 3,10 ± 1,00 (приріст ≈0,20 бала). У контрольній групі після завершення експерименту спостерігалося незначне зростання середніх показників фізичної підготовленості з 2,90 ± 1,05 до 3,10 ± 1,00 бала, а приріст результатів за більшістю тестів коливався в межах 0,15-0,25 бала. Практичне значення дослідження полягає у можливості використання розробленої корекційної програми фізичної культури в системі фізичного виховання закладів вищої освіти та під час удосконалення оздоровчих програм для студентів

Ключові слова: функціональний стан організму; індивідуальні особливості студентів; рівень фізичної активності; навчальний процес; адаптаційні можливості

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 26.12.2025.Revised: 10.04.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.894:796.015.52
DOI: 10.69587/tppcs/1.2026.81

Comparative analysis of the effectiveness of different strength training methods for the formation of muscle relief in bodybuilder athletes

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Abstract. The aim of the study was to determine how different options for organising strength loads affect the development of muscle mass, changes in body composition and expressiveness of the relief in bodybuilder athletes. The study was conducted at the Uman National University (Ukraine) from October 20 to December 12, 2025 with the participation of 66 male bodybuilder athletes who performed 8-week programmes of traditional hypertrophic training, drop sets and periodised strength-hypertrophic training, and the effectiveness was assessed using a pedagogical experiment, bioimpedance analysis, anthropometry, single-repetition maximum testing, calculation of the total strength index and statistical analysis. The most significant changes in body composition occurred in the periodised strength-hypertrophic training group: skeletal muscle mass increased by 2.4 kg, lean mass by 2.6 kg, and the proportion of adipose tissue decreased by 2.3%, which is explained by the combination of high mechanical stress in basic exercises with sufficient hypertrophic volume in auxiliary movements. Anthropometric indicators confirmed the improvement of the relief: shoulder girth increased by 1.6 cm, chest by 2.5 cm, hips by 2.3 cm, while the waist decreased by 2.9 cm, which reflects the improvement of body proportions. The total strength index increased by 57.2 kg versus 31.7 kg in the drop-set group and 29.9 kg in the traditional method group, confirming the advantage of periodisation for the development of maximum strength. Correlation analysis showed a relationship between skeletal muscle mass gain and strength index ($r = 0.74$), and waist reduction – with a decrease in adipose tissue ($r = 0.72$), which proves the interdependence of morphological and functional changes. Thus, periodised strength-hypertrophic training most effectively combined muscle mass gain, fat component reduction, improvement of proportions and strength increase in bodybuilders. The results can be used by bodybuilding coaches, physical education and sports specialists and athletes to plan training programmes aimed at the formation of muscle relief and control of body composition

Keywords: body composition; fat-free mass; anthropometric parameters; adaptation; hypertrophy; morphological changes; drop set

Introduction

In bodybuilding, the selection of a strength training technique determines not only the increase in muscle mass, but also the expressiveness of the muscle relief, the proportionality of the physique and the stability of changes in body composition. The effectiveness of training depends on the combination of skeletal muscle hypertrophy, a decrease in the fat component, the optimal volume of the load, the intensity of exercises and full recovery. Different training techniques have different effects on mechanical stress, metabolic stress, local muscle fatigue and the adaptive capabilities of the body, so the effectiveness should be assessed by morphological and strength indicators. Incorrect selection of loads can cause excessive fatigue, trauma, disproportionate development of muscle groups and unstable changes in the ratio of muscle and fat mass, since the body does not have time to fully recover between workouts, and

Suggested Citation: Pyzhianov, V., & Semenovo, A. (2026). Comparative analysis of the effectiveness of different strength training methods for the formation of muscle relief in bodybuilder athletes. *Theory and Practice of Physical Culture and Sports*, 5(1), 81-95. doi: 10.69587/tppcs/1.2026.81.

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individual muscle groups receive either excessive or insufficient stimulus for adaptation. Under such conditions, the quality of the hypertrophic response decreases, body composition control deteriorates, and it becomes more difficult to achieve a pronounced muscle relief.

The training of bodybuilders involves combining the selection of exercises with the planning of a training system in which the volume of the load, intensity, recovery, adaptation control, and targeted morphological changes are functionally interconnected. The problem of scientific support for strength sports was analysed by L. Podrigalo *et al.* (2025), focusing on areas of research related to strength training, functional capabilities of athletes, training effectiveness, and risks of overload. The results demonstrated the need to consider strength training not only as a means of increasing strength, but also as a controlled process of the body's adaptation to repetitive loads. Methodological approaches to the systematic training of bodybuilders were considered by S.I. Karaulova & A.Y. Troian (2024), focusing on planning training stages, selecting exercises, regulating intensity, and taking into account the level of fitness of athletes. Researchers proved that the effectiveness of bodybuilders' training is determined not only by the total amount of work performed, but also by the structure of the training programme, in particular, the sequence of exercises, load distribution, intensity, and compliance of the training effect with the training stage. Optimisation of training loads in novice athletes specialising in bodybuilding was studied by S.I. Karaulova *et al.* (2025). The authors showed that gradual dosing of volume and intensity contributes to the formation of adaptation, while the mismatch of the load to the level of fitness limits the increase in muscle mass and increases the risk of functional exhaustion.

Morphological changes in bodybuilding are formed under the influence of the loading mode, the type of exercises and the nature of energy supply, therefore, the assessment of the effectiveness of the training method should cover not only the strength result, but also the dynamics of girths, muscle mass and functional state. Changes in the girth dimensions of the body of bodybuilders under the influence of training exercises, free weight and various loading modes were investigated by V. Potop *et al.* (2023). The results confirmed that girth parameters reflect the local direction of hypertrophic changes and can be used as an applied criterion for assessing muscle relief. The features of the adaptive reactions of bodybuilders were clarified in the work of A. Chernozub *et al.* (2023), which analysed the influence of various energy supply modes, load intensity, training exercises and free weight exercises on the morphofunctional indicators of athletes. The authors found that the combination of exercises in simulators and exercises with free weights forms a different morphofunctional response, which confirms the need to compare training methods by several indicators. Control of the functional state of athletes during physical exertion was considered by Y. Mykhaliuk *et al.* (2025). The results obtained showed that monitoring of functional reactions is necessary to assess load tolerance and prevent the accumulation of fatigue.

The formation of muscle relief in bodybuilding is associated with the simultaneous development of muscle mass, a decrease in the fat component, an increase in local muscle expressiveness and the use of techniques that combine mechanical tension with metabolic stress. The construction of the training process of qualified bodybuilders in the competitive period was studied in the work of O.B. Piven *et al.* (2023), where attention is focused on the relationship between muscle mass development, physique improvement and the selection of training equipment. Researchers established that the effectiveness of training in the competitive period depends on the targeted regulation of the volume and intensity of the load, since it is these parameters that affect the preservation of muscle mass and the improvement of the visual characteristics of the physique. The effect of drop sets on uneven hypertrophy of the quadriceps femoris muscle was studied by D. Varović *et al.* (2021). The authors found that this method can cause local differences in the increase in muscle thickness; for bodybuilding, this means the possibility of targeted influence on individual muscle segments, on which the visual detail of the physique depends. L.K. Sødal *et al.* (2023) summarised the data on the effect of drop sets on skeletal muscle hypertrophy, analysing the results of studies with different strength load protocols. Scientists found that drop sets can provide a hypertrophic stimulus due to a combination of high local fatigue, increased muscle time under load and approaching muscle failure, however, the effectiveness is determined by the total volume of work, intensity, and place of this technique in the training programme.

Previous studies did not sufficiently reveal the comparative effectiveness of different strength training methods in bodybuilders in terms of a set of indicators of muscle relief, body composition, girth parameters and strength fitness. The aim of the study was to establish the effectiveness of different training approaches in ensuring morphological and strength changes associated with improving the physique of bodybuilders. The objectives of the study were: to assess the initial indicators of body composition, girth parameters and strength fitness of bodybuilders; to determine changes in muscle mass, fat component and strength indicators after applying different strength training methods; to compare the effectiveness of the studied methods according to morphological and functional criteria.

Materials and Methods

Design, basis and ethical principles of the study. The study had an empirical comparative design with elements of a pedagogical experiment, as it involved the targeted application of different strength training techniques and the subsequent comparison of the impact on the morphological and strength indicators of bodybuilder athletes. The study was conducted at the Uman National University, Uman, Ukraine. The choice of this research was due to the profile of the university, which trained specialists in speciality 017 Physical Culture and Sports, in particular, in the educational programmes "Physical Culture and Sports" and "Fitness and Recreation"; this base ensured the involvement of some participants with experience in strength training, the organisation of classes in an educational and sports environment and the control of the technique of performing exercises, training load, anthropometric and strength indicators under the same conditions. The experimental phase lasted 8 weeks – from October 20 to December 12, 2025. This period was chosen due to the stability of the training schedule in the first semester, as it did not coincide with

holidays, examination sessions and long holiday breaks. The eight-week mesocycle was sufficient to detect initial morphological and strength changes in athletes with experience in strength training, provided the same number of training microcycles for all groups, and did not create an excessive risk of accumulating chronic fatigue.

The study was conducted in accordance with the ethical principles of The Declaration of Helsinki (2024) for research involving human subjects, which provided for voluntary participation, obtaining informed consent, prior assessment of potential risks, confidentiality of personal data and the right of participants to discontinue participation at any stage without negative consequences. The experiment was approved by the Ethics Committee of the Uman National University, protocol No. 4 dated October 1, 2025.

Sample formation and characteristics of study participants. The study included 66 male bodybuilders aged 19 to 32 years, who systematically engaged in strength training and had experience in bodybuilding training from 2 to 6 years. The average age of the participants was 24.8 ± 3.1 years, the average training experience was 4.2 ± 1.1 years. Only men were included in the sample, since the study was aimed at comparing training methods, and not at analysing gender differences. The homogeneity of the sample by gender made it possible to reduce the influence of biological factors on the assessment of changes in muscle mass, body composition and strength indicators.

The sample was formed purposefully; the selection of participants was carried out in two stages. At the first stage, information about the study was disseminated at the university through an information announcement at the department, messages in the faculty's educational and sports groups, verbal information to students during classes in sports and practical disciplines, and appeals to teachers and coaches who worked with students who systematically engaged in strength sports. Additionally, the recruitment message was transmitted through coaches of Uman sports clubs and placed in gyms where amateur bodybuilders trained. Of the 66 participants, 30 were students of the Uman National University in the 2nd-4th year of the bachelor's degree and the 1st year of the master's degree, and 36 were athletes who trained in Uman sports clubs and underwent testing and training intervention at the faculty. This method of forming the sample made it possible to attract athletes with sufficient experience in strength training and ensure that measurements were carried out under the same conditions. At the second stage, those wishing to participate in the study filled out a primary selection questionnaire (Table 1).

Table 1. Questionnaire for selecting bodybuilder athletes to participate in the study

Questionnaire block	Question / indicator	Answer option or method of fixation
General information	Last name, first name or individual participant code	Researcher's note
	Age	Full years
	Sex	Male
	Participant status	Student of Uman National University / athlete of the Uman sports club
	For students: course of study	2nd / 3rd / 4th year of undergraduate studies / 1st year of graduate studies
Training experience	Total strength training experience	Number of years
	Bodybuilding experience	Number of years
	Average training frequency per week	3 / 4 / 5 / 6 or more times
	Duration of one workout	Up to 60 min / 60–90 min / over 90 min
	Experience in bodybuilding competitions	Yes / no
	The main type of preliminary training program	Split programme / full body / strength programme / mixed program
	Were drop sets used before?	Yes / no / occasionally
	Was load periodisation used before?	Yes / no / partially
Health status	Presence of acute musculoskeletal injuries in the last 3 months	Yes / no
	Presence of chronic diseases in the acute stage	Yes / no
	The presence of medical contraindications to strength training	Yes / no
	A break in training of more than 2 weeks in the last 3 months	Yes / no
Mode and recovery	Average sleep duration	Less than 6 hours / 6–7 hours / 7–8 hours / more than 8 hours
	The presence of additional intense physical activity outside of bodybuilding	Yes / no
Food	Is changing diet for 8 weeks planned?	Yes / no
	Does the participant maintain a stable protein diet?	Yes / no / partially
Control of experimental conditions	Willingness to train according to a specific program	Yes / no
	Willingness not to change the number of sets, repetitions, and exercises	Yes / no
	Willingness to undergo initial and repeated testing	Yes / no
Ethical consent	Confirmation of voluntary participation	Yes / no
	Confirmation of familiarisation with possible loading risks	Yes / no
	Consent to the processing of anonymised research results	Yes / no

Source: developed by the authors

After the questionnaire, a short interview was conducted and, if available, a review of the athlete's training diary or self-report data. Additionally, during the familiarisation training, the technique of performing basic strength exercises was assessed to confirm the participants' ability to safely perform bench presses, squats, pulling movements and auxiliary exercises according to the experimental programme, with such assessment being used as a criterion for admission to participation and safety control, and not as a separate outcome indicator of the study. Final inclusion in the sample was carried out after confirmation of compliance with the criteria: male gender; age 19-32 years; experience of systematic strength training from 2 to 6 years; regular bodybuilding classes at least 4 times a week; absence of acute injuries of the musculoskeletal system; absence of medical contraindications to strength loads; willingness to adhere to a specific training programme for 8 weeks; consent to undergo anthropometric, compositional and strength testing. Exclusion criteria were: the presence of acute or chronic diseases in the acute stage; injuries to muscles, ligaments, or joints that limited the performance of strength exercises; a break in training for more than 2 weeks during the last 3 months; irregular attendance at classes during the experiment; independent change of the training program; abrupt change in diet; use of pharmacological agents that could affect muscle mass, water balance or recovery; refusal to participate at any stage of the study.

Participants were divided into three experimental groups of 22 participants. The distribution was carried out taking into account age, training experience, body weight, percentage of adipose tissue and the initial level of strength training, so that the groups were comparable in terms of basic morphological and functional characteristics and to minimise the impact of initial differences on the interpretation of the results. The first group included athletes who trained using the traditional hypertrophic method; the second – athletes who performed training using drop sets; the third – athletes who trained using the periodised strength-hypertrophic method. Initially, 72 bodybuilder athletes were included in the experiment, who were divided into three groups of 24 people. During the study, 4 participants dropped out: in the first group – 2 participants due to irregular attendance at classes, in the second group – 1 participant due to a change in diet, in the third group – 1 participant due to a domestic injury not related to the implementation of the training programme. To maintain the same number of groups and the correctness of the statistical comparison, before the final analysis, data from 2 more participants were randomly removed from the groups in which more athletes remained after the end of the experiment. The final analysis included the results of 66 bodybuilders.

Organisation and methods of training of the experimental groups. After the initial testing, the participants performed training programmes for 8 weeks according to the group distribution. In all groups, classes were held 4 times a week (Monday, Wednesday, Friday, Saturday) according to the same split microcycle structure. The first class was aimed at working out the pectoral muscles and triceps, the second – the back and biceps muscles, the third – the lower limb muscles, the fourth – the deltoid muscles, core muscles and additional work on muscle groups that needed correction. This structure made it possible to ensure recovery between repeated loads on the same muscle groups and to standardise the frequency of training exposure in all experimental groups. The duration of one session was 70-90 minutes. Each training session had the same structure: the preparatory part lasted 10-12 minutes, the main part – 50-65 minutes, the final – 5-8 minutes. In the preparatory part, light cardio warm-up, joint mobilisation and 1-2 approaches to the first basic exercise were used. The main part contained strength exercises according to the methodology of a specific group. In the final part, respiratory recovery, relaxation exercises and short stretching of the muscle groups that received the main load were used.

To reduce the impact of differences in the total training volume, the number of training days, the structure of the microcycle, the duration of classes and the number of basic exercises were standardised for all groups. The total training volume was controlled by the number of working sets and repetitions within each training day; the differences between the groups were primarily in the way the intensity was organised, the use of drop sets or wave-like progression, and not in changing the frequency of training or the overall structure of the programme.

The working weight for each participant was determined individually based on the results of the initial testing of the one-repetition maximum (1RM, kg) in basic exercises; in these movements, the intensity was set as a percentage of the 1RM. In auxiliary and isolated exercises, the load was selected based on the target repetition range, technically correct amplitude of movement, and the absence of premature violation of technique. If the participant performed the upper limit of repetitions in all approaches without technical errors, the working weight in the next session was increased by 2.5-5.0%. The dynamics of strength training were analysed only by the results of basic exercises and the total strength index, while auxiliary exercises were used to standardise the training effect, maintain the overall hypertrophic volume and local work on muscle groups, and not as a separate performance criterion.

After determining individual workloads, participants performed programmes according to group distribution. The first group used a traditional hypertrophic technique, in which the main training stimulus was created through moderately high intensity, stable workload and a range of 8-12 repetitions. The load progression was carried out after the athlete technically correctly performed the upper limit of repetitions in all planned approaches. This mode was used as a basic model of strength training against which other techniques were compared (Table 2).

Table 2. Structure of the training programme of the first experimental group

Training day	Exercise	Sets × repetitions	Intensity	Rest
Day 1	Bench press	4 × 8-10	75-80% 1RM	90 s
	Incline dumbbell press	3 × 10-12	70-75% 1RM	75 s
	Lying dumbbell flyes	3 × 12	65-70% 1RM	60 s

Table 2, Continued

Training day	Exercise	Sets × repetitions	Intensity	Rest
Day 1	Push-ups on the parallel bars	3 × 8-12	body weight / additional weight	75 s
	Arm extension on the block	3 × 10-12	70% 1RM	60 s
Day 2	Incline barbell pull	4 × 8-10	75-80% 1RM	90 s
	Pull-ups / upper block pull	3 × 8-12	70-75% 1RM	75 s
	Horizontal cable row	3 × 10-12	70% 1RM	75 s
	One-arm dumbbell row	3 × 10	70-75% 1RM	75 s
	Arm curls with a barbell	3 × 10-12	70% 1RM	60 s
Day 3	Squats with a barbell	4 × 8-10	75-80% 1RM	90 s
	Leg press	3 × 10-12	70-75% 1RM	90 s
	Romanian deadlift	3 × 10	70-75% 1RM	90 s
	Leg curls in the simulator	3 × 12	65-70% 1RM	60 s
	Standing calf raises	4 × 12-15	65-70% 1RM	60 s
Day 4	Barbell/Dumbbell Overhead Press	4 × 8-10	75-80% 1RM	90 s
	Dumbbell side raises	3 × 12	65-70% 1RM	60 s
	Barbell upright row	3 × 10	70% 1RM	75 s
	Reverse dumbbell raises	3 × 12	65-70% 1RM	60 s
	Plank/Hanging Leg Raises	3 × 10-15	own body weight	60 s

Source: developed by the authors

In the second group, the main difference was the use of drop sets in the last working approach. After performing the main part of the approach, the working weight was reduced by 20-30% without a long pause, after which the athlete continued the exercise until pronounced local fatigue. In large muscle groups, one drop set was used per exercise, and in small muscle groups, no more than one drop set per training block (Table 3). This method of organising the load was aimed at increasing the time the muscles were under load, increasing metabolic stress and enhancing the local hypertrophic stimulus. The third group used a periodised strength-hypertrophic technique that combined higher-intensity work in basic exercises and a hypertrophic regime in auxiliary exercises. Basic exercises were performed at the beginning of the session, when the level of fatigue was lower and athletes could work with a higher relative weight. Auxiliary exercises were used after the strength block to increase the training volume and local work of muscle groups. The load progression was carried out in a wave-like manner: during the first three weeks, the volume and working weight gradually increased, in the fourth week the load was reduced by 15-20% for partial recovery, after which the cycle was repeated with updated working weights (Table 4).

Table 3. Structure of the training programme of the second experimental group

Training day	Exercise	Basic approaches	Drop set	Rest
Day 1	Bench press	3 × 8-10 at 75-80% 1RM	last set: -25% weight, 6-8 repetions	90 s
	Incline dumbbell press	3 × 10	last set: -20% weight, 6-8 repetions	75 s
	Lying dumbbell flyes	2 × 12	last set: -20% weight to local fatigue	60 s
	Arm extension on the block	3 × 10-12	last set: -25% weight, 6-10 repetions	60 s
Day 2	Incline barbell pull	3 × 8-10 at 75-80% 1RM	last set: -20% weight, 6-8 repetions	90 s
	Upper-block pulldown	3 × 10-12	last set: -25% weight, 6-10 repetions	75 s
	Horizontal cable row	3 × 10	last set: -20% weight, 6-8 repetions	75 s
	Arm curls with a barbell	3 × 10-12	last set: -20% weight, 6-10 repetions	60 s
Day 3	Squats with a barbell	3 × 8-10 at 75-80% 1RM	last set: -20% weight, 6-8 repetions	90 s
	Leg press	3 × 10-12	last set: -25% weight, 8-10 repetions	90 s
	Romanian deadlift	3 × 10	last set: -20% weight, 6-8 repetions	90 s
	Leg curls in the simulator	3 × 12	last set: -25% weight to local fatigue	60 s
	Standing calf raises	3 × 12-15	last set: -25% weight, 8-12 repetions	60 s
Day 4	Dumbbell Overhead Press	3 × 8-10	last set: -20% weight, 6-8 repetions	90 s
	Dumbbell side raises	3 × 12	last set: -25% weight to local fatigue	60 s
	Barbell upright row	3 × 10	last set: -20% weight, 6-8 repetions	75 s
	Reverse dumbbell raises	3 × 12	last set: -20% weight to local fatigue	60 s
	Hanging leg raises/twists	3 × 12-20	without drop set	60 s

Source: developed by the authors

Table 4. Structure of the training programme of the third experimental group

Training day	Exercise	Strength block	Hypertrophic block	Rest
Day 1	Bench press	4 × 4-6 at 80-88% 1RM	-	120 s
	Incline dumbbell press	-	3 × 8-12 at 70-75% 1RM	75-90 s
	Lying dumbbell flyes	-	3 × 10-12 at 65-70% 1RM	60 s
	Push-ups on the parallel bars	-	3 × 8-10	75 s
	Arm extension on the block	-	3 × 10-12	60 s
Day 2	Incline barbell pull	4 × 4-6 at 80-88% 1RM	-	120 s
	Pull-ups / upper block pull	-	3 × 8-12 at 70-75% 1RM	75-90 s
	Horizontal cable row	-	3 × 10-12 at 70% 1RM	75 s
	One-arm dumbbell row	-	3 × 10	75 s
	Arm curls with a barbell	-	3 × 10-12	60 s
Day 3	Squats with a barbell	4 × 4-6 at 80-88% 1RM	-	120 s
	Leg press	-	3 × 8-12 at 70-75% 1RM	90 s
	Romanian deadlift	-	3 × 8-10 at 70-75% 1RM	90 s
	Leg curls in the simulator	-	3 × 10-12	60 s
	Standing calf raises	-	4 × 12-15	60 s
Day 4	Barbell/Dumbbell Overhead Press	4 × 4-6 at 80-85% 1RM	-	120 s
	Dumbbell side raises	-	3 × 10-12	60 s
	Barbell upright row	-	3 × 8-10	75 s
	Reverse dumbbell raises	-	3 × 10-12	60 s
	Plank/Hanging Leg Raises	-	3 sets	60 s

Source: developed by the authors

Individual correction of the programmes concerned only the working weight, the rate of progression and the technical safety of the exercises; the list of basic exercises remained the same within each group. If discomfort appeared, the amplitude or variant of the exercise was adjusted without changing its muscular focus. Individual dietary programmes were not prescribed: participants were recommended to maintain the usual diet and drinking regimen, not to drastically change calorie content, protein intake and fluid volume, especially 24 hours before measuring body composition.

Methods of evaluating research indicators. The assessment was carried out twice: 2-3 days before the start of the experiment and 48-72 hours after the last training session. This interval was used to reduce the influence of acute post-training fatigue, local muscle swelling and short-term fluctuations in body weight on the measurement results. All measurements were performed in the morning, before training, in approximately the same hydration conditions and after refraining from intensive loads the day before. Body composition was assessed by body weight, percentage of adipose tissue, lean mass and skeletal muscle mass. For this purpose, the method of bioelectrical impedance analysis was used on the Tanita MC-780MAP body composition analyser (Japan). Measurements were performed in a standing position, barefoot, with contact of the feet and hands with the electrodes of the device; before the procedure, the participant's age, gender, and height (cm) were entered into the system, after which the device automatically calculated body composition indicators based on the electrical resistance of the tissues. Body weight (kg) was determined by the analyser's built-in scales, and the percentage of adipose tissue (%), lean mass (kg) and skeletal muscle mass (kg) were recorded according to the device's protocol without additional manual formulae. Before the measurement, the participants did not perform intensive physical activity for 24 h, did not drink a large amount of fluid immediately before the procedure, did not eat for at least 3 h before testing, and were measured at the same time of day, which reduced the error associated with fluctuations in water balance.

Anthropometric measurements included shoulder, chest, waist, and hip circumferences, which were recorded in centimetres using a flexible inelastic anthropometric tape with an accuracy of 0.5 cm. Upper arm circumference was measured in the middle third of the shoulder with the biceps tense; chest circumference – at the level of the nipple line after a calm exhalation; waist circumference – at the level of the smallest torso circumference; hip circumference – in the upper third of the thigh. During the measurement, the tape was placed horizontally, without excessive compression of soft tissues. Each measurement was performed three times, after which the average value was used for analysis.

Strength training was assessed based on the results of 1RM in three basic exercises: bench press, barbell squat, and deadlift. Testing was performed after a 10-minute general warm-up and a special warm-up in the corresponding exercise, which included 2-3 sets of approaches with a gradual increase in load. After each attempt, the participant rested for 3-5 minutes, which allowed reducing the impact of acute fatigue on the result of the next attempt. The maximum result was recorded as the largest weight that the athlete performed technically correctly in one repetition with a full range of motion. In the bench press, an attempt was counted if the barbell was lowered to the chest in a controlled manner and the arms were fully extended; in the squat, if the required squat depth was reached and the body was returned to the starting position independently; in the deadlift, if the body was fully straightened and the barbell was fixed without losing technique. If the athlete violated

the technique, performed the movement with incomplete amplitude or needed outside assistance, the attempt was not counted. For a generalised assessment of strength training, the total strength index (SSI, kg) was calculated as the sum of the maximum results in three basic exercises:

$$TSI = 1RM\ bench\ press + 1RM\ squat + 1RM\ deadlift, \quad (1)$$

where TSI – total strength index (kg); 1RM – the largest weight (kg) lifted by an athlete in one technically correct repetition. TSI was previously defined as an integral criterion of general strength fitness, since it summarised the results of three basic multijoint exercises and reflected functional changes in the main muscle groups after training intervention. This indicator was used to compare the general dynamics of strength fitness and functional efficiency of the studied training methods.

Methods of statistical analysis of results. Statistical analysis was performed in the Statistica 10.0 programme (USA). For each indicator, the arithmetic mean (M), standard deviation (SD), absolute (Δ) and relative (Δ%) change were determined; the results were presented in the format M ± SD. Normality of distribution was checked using the Shapiro-Wilk test. Intragroup dynamics of indicators were assessed using paired Student's t-test, intergroup differences were assessed using one-way ANOVA with a posteriori comparison using Tukey HSD. Pearson correlation analysis was used to establish relationships between changes in skeletal muscle mass, adipose tissue, girth parameters, and TSI. Pairs of indicators for correlation analysis were formed according to the principle of functional-morphological interdependence: the increase in skeletal muscle mass was compared with the change in TSI to assess the relationship between hypertrophic and strength adaptation; the decrease in the proportion of adipose tissue and waist circumference were analysed as interrelated markers of improved body composition and muscle relief; changes in shoulder, chest, and hip girths were considered in connection with the increase in lean and skeletal muscle mass as an anthropometric reflection of local muscle hypertrophy. The strength of the relationship was interpreted by the absolute value of r: up to 0.30 – low, 0.30-0.69 – medium, 0.70 and above – high. The level of statistical significance was set at $p < 0.05$.

Results

Dynamics of body composition indicators of bodybuilders. Before the start of the experiment, no statistically significant differences were found between the groups in terms of body composition indicators ($p > 0.05$), which confirmed the comparability of the initial data. After an 8-week training cycle, an increase in lean and skeletal muscle mass was recorded in all groups against the background of a decrease in the proportion of adipose tissue, however, the magnitude of these changes differed depending on the method used. The quantitative dynamics of body composition indicators in each experimental group are presented in Tables 5-7.

Table 5. Dynamics of body composition of the first experimental group

Indicator	Before the experiment	After the experiment	Δ	Δ%
Body weight, kg	82.3 ± 5.7	83.0 ± 5.6	+0.7	+0.9
Adipose tissue, %	14.9 ± 2.0	13.8 ± 1.8	-1.1	-7.4
Fat-free mass, kg	70.0 ± 4.8	71.3 ± 4.7	+1.3	+1.9
Skeletal muscle mass, kg	39.0 ± 3.1	40.1 ± 3.0	+1.1	+2.8

Note: Δ – absolute change in the indicator; Δ% – relative change from baseline; data are presented as M ± SD
Source: data obtained during the research

In the first group, after the application of the traditional hypertrophic method, a moderate improvement in body composition was established. Body weight increased by 0.7 kg, but this increase was not accompanied by an increase in the fat component, since the proportion of adipose tissue decreased from 14.9 ± 2.0% to 13.8 ± 1.8%. This indicates that the increase in body weight in athletes of this group was associated mainly with an increase in active tissue mass, and not with the accumulation of adipose tissue. Fat-free mass increased by 1.3 kg, and skeletal muscle mass by 1.1 kg. Such dynamics indicate the presence of a hypertrophic response to the traditional strength training regimen, built on the performance of 8-12 repetitions with moderately high intensity. At the same time, the relative increase in skeletal muscle mass was 2.8%, which characterises the method as stable, but gradual in terms of the pace of morphological adaptation. A 1.1 percentage point reduction in adipose tissue further indicates an improvement in the ratio between muscle and fat components, which is a necessary condition for the formation of muscle relief.

Table 6. Dynamics of body composition in the second experimental group

Indicator	Before the experiment	After the experiment	Δ	Δ%
Body weight, kg	82.0 ± 5.9	82.9 ± 5.7	+0.9	+1.1
Adipose tissue, %	14.8 ± 2.1	13.1 ± 1.9	-1.7	-11.5
Fat-free mass, kg	69.9 ± 4.9	71.6 ± 4.8	+1.7	+2.4
Skeletal muscle mass, kg	38.9 ± 3.2	40.4 ± 3.1	+1.5	+3.9

Note: Δ – absolute change in the indicator; Δ% – relative change from baseline; data are presented as M ± SD
Source: data obtained during the research

The data in Table 6 demonstrated that in the second group, after 8 weeks of using the drop-set technique, positive dynamics of body composition were also recorded. Body weight increased by 0.9 kg, while the proportion of adipose tissue decreased by 1.7 percentage points. This result indicates a simultaneous improvement in two components of physique: an increase in the mass of tissues associated with training adaptation and a decrease in relative fat content. Fat-free mass in this group increased by 1.7 kg, and skeletal muscle mass by 1.5 kg. This can be explained by the specificity of drop-sets, which increase the duration of muscle work within one approach, increase local fatigue and create higher metabolic stress. Under these conditions, muscle groups receive an additional stimulus to adapt not only through mechanical stress, but also through the accumulation of metabolites at the end of the work set. The 11.5% reduction in adipose tissue from baseline may be associated with a higher training load density and higher energy expenditure during training.

Table 7. Dynamics of body composition of the third experimental group

Indicator	Before the experiment	After the experiment	Δ	Δ%
Body weight, kg	82.5 ± 5.6	84.1 ± 5.4	+1.6	+1.9
Adipose tissue, %	15.0 ± 2.0	12.7 ± 1.7	-2.3	-15.3
Fat-free mass, kg	70.1 ± 4.7	72.7 ± 4.6	+2.6	+3.7
Skeletal muscle mass, kg	39.1 ± 3.0	41.5 ± 2.9	+2.4	+6.1

Note: Δ – absolute change in the indicator; Δ% – relative change from baseline; data are presented as M ± SD
Source: data obtained during the research

In the third group, where the periodised strength-hypertrophic technique was used, the most pronounced intragroup dynamics of body composition indicators were established. Body weight increased by 1.6 kg, but at the same time the proportion of adipose tissue decreased from 15.0 ± 2.0% to 12.7 ± 1.7%. This means that the increase in total body weight occurred against the background of a decrease in the fat component, i.e. morphological changes had a favourable direction for the formation of muscle relief. Fat-free mass increased by 2.6 kg, and skeletal muscle mass by 2.4 kg, which indicates a pronounced hypertrophic response. This nature of the changes may be associated with the combination of two training stimuli: strength approaches with higher intensity, which increased mechanical stress, and hypertrophic approaches in auxiliary exercises, which provided a sufficient amount of local muscle work. The 2.3 percentage point decrease in adipose tissue further indicates an improvement in the ratio between active and fat body mass. Thus, within this group, the periodised load structure provided a combination of muscle gains with a decrease in the relative fat content.

The intergroup comparison showed that all three methods contributed to the improvement of body composition, but the severity of the changes was different. In the first group, the traditional hypertrophic method provided an increase in skeletal muscle mass by 1.1 kg and fat-free mass by 1.3 kg, reflecting a gradual morphological adaptation. In the second group, drop sets provided a greater increase in skeletal muscle mass – 1.5 kg – and a more noticeable decrease in adipose tissue by 1.7 percentage points, which may be associated with a higher load density and more pronounced local fatigue. The largest changes were recorded in the third group: skeletal muscle mass increased by 2.4 kg, fat-free mass – by 2.6 kg, the proportion of adipose tissue decreased by 2.3 percentage points. The obtained dynamics indicate that for the formation of muscle relief, not only an increase in the volume of work performed was decisive, but also the method of its organisation. The most favourable result was provided by the programme in which strength approaches with greater intensity were combined with a hypertrophic mode of auxiliary exercises, since such a structure simultaneously maintained mechanical tension, sufficient local volume of load and fatigue control.

Changes in anthropometric parameters of the formation of muscle relief. After an 8-week experiment, changes in anthropometric parameters confirmed the different orientation of the athletes' adaptation to the three methods of strength training. In all groups, an increase in shoulder, chest and hip girths was observed, however, the rate of growth of muscle segments was not the same. Simultaneous reduction of waist circumference showed improvement of body proportions, and the most pronounced combination of increase of peripheral circumferences and decrease of central circumference was characteristic of periodised power-hypertrophic technique. Quantitative dynamics of anthropometric parameters of bodybuilders is given in Table 8.

Table 8. Dynamics of anthropometric parameters of bodybuilder athletes

Indicator	Group	Before the experiment	After the experiment	Δ	Δ%
Upper arm circumference, cm	Group 1	39.3 ± 1.9	40.2 ± 1.8	+0.9	+2.3
	Group 2	39.1 ± 2.0	40.4 ± 1.9	+1.3	+3.3
	Group 3	39.4 ± 1.8	41.0 ± 1.7	+1.6	+4.1
Chest circumference, cm	Group 1	105.2 ± 4.7	106.6 ± 4.6	+1.4	+1.3
	Group 2	105.0 ± 4.9	106.8 ± 4.7	+1.8	+1.7
	Group 3	105.5 ± 4.6	108.0 ± 4.4	+2.5	+2.4
Waist circumference, cm	Group 1	82.4 ± 4.1	81.0 ± 3.9	-1.4	-1.7
	Group 2	82.1 ± 4.3	80.2 ± 4.0	-1.9	-2.3
	Group 3	82.6 ± 4.0	79.7 ± 3.8	-2.9	-3.5

Table 8, Continued

Indicator	Group	Before the experiment	After the experiment	Δ	Δ%
Hip girth, cm	Group 1	61.7 ± 3.0	62.8 ± 2.9	+1.1	+1.8
	Group 2	61.6 ± 3.2	63.2 ± 3.0	+1.6	+2.6
	Group 3	61.8 ± 3.1	64.1 ± 3.0	+2.3	+3.7

Note: Δ – absolute change in the indicator; Δ% – relative change from baseline; data are presented as M ± SD
Source: data obtained during the research

The results presented in Table 8 showed that anthropometric dynamics had not only quantitative but also structural differences between the groups. In the first group, the increase in girths was uniform but moderate: the shoulder increased by 0.9 cm, the chest – by 1.4 cm, the thigh – by 1.1 cm. This pattern of changes corresponded to the traditional hypertrophic method, in which muscle groups received a stable training stimulus without a sharp increase in work density or change in intensity within the microcycle. The 1.4 cm waist reduction complemented the increase in peripheral girths, but the overall morphological effect in this group was mostly gradual.

In the second group, anthropometric changes were more pronounced, especially in shoulder and thigh girths. Compared to the first group, the increase in the shoulder was 0.4 cm greater, the hip – 0.5 cm, the chest – 0.4 cm, and the waist – 0.5 cm. This indicated that drop sets create a more intense local stimulus for muscle segments that perform work to pronounced fatigue after weight loss. This mode increases metabolic stress and the duration of muscle tension, so the increase in girth was greater than with the traditional method. At the same time, the advantage of drop sets remained moderate, since this method had a greater effect on local load density than on the systemic combination of strength, volume, and recovery.

The third group recorded the most pronounced change in the anthropometric profile. Compared to the first group, the increase in the shoulder was 0.7 cm greater, the chest – 1.1 cm, the hips – 1.2 cm, and the waist – 1.5 cm smaller; compared to the second group, the advantage was 0.3 cm, 0.7 cm, 0.7 cm, and 1.0 cm, respectively. This indicated that under the conditions of standardised training frequency, split microcycle structure, training duration, and number of basic exercises, the periodised strength-hypertrophic technique was associated with a greater increase in individual girths and a more pronounced improvement in body proportions. At the same time, since the detailed calculation of the total load volume according to the formula "weight × repetition × sets" was not a separate outcome indicator of this study, the advantage of the third group should be interpreted as the result of a comprehensive organisation of the training effect, and not in isolation as an effect of periodisation. This result can be explained by the fact that power approaches with higher intensity created sufficient mechanical stress for large muscle groups, and hypertrophic approaches in auxiliary exercises supported the local volume of work. Due to this, the increase in the shoulder, chest, and thigh was combined with the greatest decrease in the waist.

The most indicative for assessing muscle relief was not an isolated increase in individual girth, but the ratio between the increase in muscle segments and the decrease in the central girth of the trunk. In the first group, this ratio changed moderately, which corresponded to the gradual adaptation to the standard hypertrophic load. In the second group, the relief increased mainly due to greater local fatigue and work density, which contributed to better dynamics of the shoulder, hip, and waist. In the third group, the changes were the most balanced, since the development of the upper and lower muscle segments was accompanied by the most noticeable reduction in the waist. Therefore, within the framework of the applied programme, the periodised approach was associated with the most favourable combination of muscle girth growth and improvement of body proportions, however, the interpretation of this advantage should take into account the lack of a separate quantitative comparison of the total training volume between the groups.

Dynamics of strength training of athletes of the experimental groups. Strength indicators after an 8-week training cycle increased in all experimental groups, however, the greatest differences between the methods were manifested not in the fact of the increase itself, but in its scale and distribution between basic exercises. The traditional hypertrophic programme provided a gradual increase in results, drop sets gave similar but slightly higher dynamics, while the periodised power-hypertrophic technique provided the greatest increase in bench press, squat, deadlift and TSI. Throughout the experiment, the technical stability of the basic exercises was monitored during training sessions and repeated strength testing. No systematic technical violations were recorded in any of the groups that would require the removal of test results or changes in the load programme. In the drop sets group, local fatigue at the end of the working approaches required more frequent coaching control of the amplitude and pace of movement, but did not lead to a loss of technical suitability for performing the basic exercises. To summarise these changes, TSI was calculated using formula (1). The obtained TSI values were used to compare the integral strength dynamics between the experimental groups. Quantitative changes in the strength training of athletes are given in Table 9.

Table 9. Dynamics of strength training of athletes of experimental groups

Indicator	Group	Before the experiment	After the experiment	Δ	Δ%
Bench press, kg	Group 1	108.4 ± 11.8	116.1 ± 11.5	+7.7	+7.1
	Group 2	108.0 ± 12.0	116.4 ± 11.6	+8.4	+7.8
	Group 3	108.7 ± 11.7	123.5 ± 11.2	+14.8	+13.6

Table 9, Continued

Indicator	Group	Before the experiment	After the experiment	Δ	Δ%
Squats with a barbell, kg	Group 1	142.1 ± 15.9	152.8 ± 15.4	+10.7	+7.5
	Group 2	141.9 ± 16.1	153.0 ± 15.6	+11.1	+7.8
	Group 3	142.6 ± 15.7	162.9 ± 15.1	+20.3	+14.2
Deadlift, kg	Group 1	166.2 ± 17.6	177.7 ± 17.1	+11.5	+6.9
	Group 2	165.8 ± 17.9	178.0 ± 17.2	+12.2	+7.4
	Group 3	166.7 ± 17.4	188.8 ± 16.8	+22.1	+13.3
Total power index, kg	Group 1	416.7 ± 41.8	446.6 ± 40.7	+29.9	+7.2
	Group 2	415.7 ± 42.4	447.4 ± 40.9	+31.7	+7.6
	Group 3	418.0 ± 41.2	475.2 ± 39.8	+57.2	+13.7

Note: Δ – absolute change in the indicator; Δ% – relative change from baseline; data are presented as M ± SD
Source: data obtained during the research

In the bench press, the gains in the first and second groups were similar: 7.7 kg and 8.4 kg, respectively. This indicates that the traditional hypertrophic regimen and drop sets provided a similar level of adaptation in the bench press movement, although the gains were slightly higher in the drop sets group. The additional weight reduction in the last approach increased the local load on the pectoral muscles, triceps and anterior deltoids, but did not create the neuromuscular stimulus that is characteristic of regular work with higher percentages of the one-repetition maximum. That is why the third group demonstrated a significantly greater gain in the bench press – 14.8 kg, which was almost twice the result of the first group.

In the barbell squat, the difference between the methods was even more pronounced. In the first group, the result increased by 10.7 kg, in the second – by 11.1 kg, while in the third – by 20.3 kg. Such dynamics show that the lower limbs responded better to the programme, where the basic exercise was performed in the power block with greater intensity. For the squat, this is explained by the fact that the exercise requires not only muscle hypertrophy, but also effective intermuscular coordination, stabilisation of the trunk and the ability to maintain technique under high load. The periodised technique, unlike the other two, combined a strength stimulus with a subsequent hypertrophic load on the muscles of the lower limbs, which explains the greater increase in the result.

A similar pattern was observed in the deadlift. The increase in the first group was 11.5 kg, in the second – 12.2 kg, and in the third – 22.1 kg. The difference between the traditional method and drop sets was small, indicating a limited effect of additional local fatigue on the development of maximum strength in a complex pulling movement. Deadlift depends on the ability to mobilise large muscle masses, maintain tension in the back and lower limbs, and effectively coordinate movement throughout the kinematic link. Therefore, the greatest increase in the third group can be explained by the regular performance of basic exercises in a higher intensity mode and controlled load progression.

The TSI showed an integral advantage of the periodised approach. In the first group, it increased by 29.9 kg, in the second – by 31.7 kg, and in the third – by 57.2 kg. Thus, drop sets only slightly exceeded the traditional method in terms of overall strength gain, while the periodised programme provided almost double the increase compared to the first group. This indicates that for the development of strength training in bodybuilders, it is not enough to simply increase the volume or density of the load; it is necessary to systematically include strength approaches with a higher relative weight that stimulate neuromuscular adaptation.

The generalisation of the strength results showed that all methods provided positive dynamics, but the training effect had a different direction. The traditional hypertrophic programme formed a stable increase in strength due to an increase in muscle volume and repetition of the load. Drop sets increased local muscle fatigue and could maintain strength gains due to greater training stress at the end of the approach, but the impact on maximum results was limited. The periodised strength-hypertrophic technique provided the best strength dynamics, as it combined mechanical stress, work with higher intensity, sufficient hypertrophic volume and recovery control during the microcycle.

Correlations of morphological and strength changes in athletes. Correlation analysis made it possible to clarify which morphological changes were most closely associated with the increase in strength training after an 8-week training cycle. The closest relationships were established between the increase in skeletal muscle mass and the increase in TSI, as well as between the increase in hip circumference and the results in squat and deadlift. In contrast, the decrease in adipose tissue had a weaker, but statistically significant relationship with strength indicators, which indicated its greater role in the formation of relief than in the direct increase in maximum strength (Table 10).

Table 10. Correlations of compositional, anthropometric and strength indicators

A pair of indicators	r	p	Interpretation
Skeletal muscle mass gain – total strength index gain	0.74	<0.001	high direct connection
Gain in lean mass – gain in total strength index	0.69	<0.001	medium direct connection
Reduction of adipose tissue – increase in total strength index	0.38	0.002	medium direct connection
Shoulder girth gain – bench press gain	0.58	<0.001	medium direct connection
Chest girth gain – bench press gain	0.61	<0.001	medium direct connection
Hip circumference gain – squat gain	0.67	<0.001	medium direct connection

Table 10, Continued

A pair of indicators	r	p	Interpretation
Hip circumference increase – deadlift increase	0.63	<0.001	medium direct connection
Waist reduction – reduction of adipose tissue	0.72	<0.001	high direct connection
Decrease in waist circumference – increase in skeletal muscle mass	0.41	0.001	medium direct connection

Note: r – Pearson correlation coefficient; p – statistical significance level; analysis performed on 66 bodybuilders
Source: data obtained during the study

The closest correlation was established between the increase in skeletal muscle mass and the increase in TSI ($r = 0.74$; $p < 0.001$). This result showed a pronounced association between the growth of the muscle component and the improvement of results in basic strength exercises, but did not give grounds to interpret it as a direct cause-and-effect effect. The performance of bench press, squat and deadlift depends not only on the volume of active muscle tissue, but also on the movement technique, intermuscular coordination, the ability to stabilise the body under load and the efficiency of neuromuscular regulation. Thus, the increase in skeletal muscle mass created a morphological basis for strength progress, but the realisation of this potential was also determined by the quality of motor control.

The increase in lean mass also had a pronounced direct relationship with the increase in TSI ($r = 0.69$; $p < 0.001$). This indicator confirmed the general direction of adaptation to the training load, but was less specific compared to skeletal muscle mass, since fat-free mass includes not only muscle tissue, but also other components of the body. Therefore, its connection with force dynamics reflected a broader morphofunctional effect of training, but less accurately characterised the hypertrophic response. A decrease in the proportion of adipose tissue correlated with an increase in TSI weaker ($r = 0.38$; $p = 0.002$), which indicated a different functional content of this indicator. A decrease in the fat component primarily reflected an improvement in body composition and conditions for visualisation of the relief, while its contribution to an increase in maximum strength was indirect.

The correlations between girth parameters and the results of individual strength exercises had an anatomically justified direction. Increases in shoulder and chest girth were associated with improved bench press performance ($r = 0.58$ and $r = 0.61$; $p < 0.001$), indicating a relationship between upper body muscle segment development and bench press strength. Changes in hip girth were correlated with increases in squat ($r = 0.67$; $p < 0.001$) and deadlift ($r = 0.63$; $p < 0.001$), as these exercises involve the lower limb muscles, gluteal region, and posterior chain. This confirmed that local anthropometric changes were not isolated morphological manifestations, but reflected functional strengthening of those muscle groups involved in the execution of basic movements.

The relationship between the decrease in waist circumference and the decrease in the percentage of adipose tissue ($r = 0.72$; $p < 0.001$) had a separate interpretative value. The high value of the correlation coefficient showed that the decrease in waist circumference did not reflect random fluctuations in measurement, but a real improvement in body composition associated with a decrease in the fat component. The moderate correlation between the decrease in waist circumference and the increase in skeletal muscle mass ($r = 0.41$; $p = 0.001$) additionally demonstrated the complex nature of the formation of the relief: the visual result was determined not only by muscle hypertrophy, but also by a decrease in the central girth of the trunk. Thus, the correlation analysis showed that the effectiveness of training methods should be assessed by a combination of three blocks of indicators: the increase in skeletal muscle mass, changes in local girths and a decrease in the fat component. It is this set of parameters that most fully reflects both the strength and visual-morphological results of bodybuilders' training.

Discussion

The results obtained showed that all the studied strength training methods contributed to positive changes in body composition, anthropometric parameters and strength training of bodybuilders, but the effectiveness was not the same. The traditional hypertrophic method provided a moderate but stable adaptation. Drop sets enhanced the growth of individual muscle girths and the reduction of the fat component due to a higher work density. The most pronounced changes were observed after periodised strength-hypertrophic training, which combined the growth of skeletal muscle mass, a decrease in the proportion of adipose tissue, an improvement in body proportions and the greatest increase in strength indicators.

The most pronounced positive dynamics of body composition were recorded after the use of the periodised strength-hypertrophic technique: skeletal muscle mass increased by 2.4 kg, lean mass by 2.6 kg, and the fat component decreased by 2.3%. In the drop-set group, the increase in skeletal muscle mass was 1.5 kg, lean mass by 1.7 kg, and the reduction in the fat component by 1.7%, while with the traditional hypertrophic technique, the corresponding changes were less pronounced – 1.1 kg, 1.3 kg, and 1.1%. The results obtained are consistent with the conclusions of A.J. Graybeal *et al.* (2020), who showed that the assessment of body composition in bodybuilders requires precise methodological control due to possible discrepancies between multicomponent models and impedance devices. This confirms the feasibility of interpreting changes in fat, lean and skeletal muscle mass together with anthropometric and strength indicators. Changes in body composition and strength abilities in fitness and bodybuilding athletes were analysed by J. Caha *et al.* (2021). The authors' results coincide with the identified trend, since the increase in the muscle component was accompanied by an improvement in strength indicators. In the work of B.J. Schoenfeld *et al.* (2020), changes in body composition, strength and metabolic characteristics during the training of a natural bodybuilder were described. The difference is that the mentioned study had a clinical case format and covered eating behaviour, while in this experiment, nutrition was only controlled as an external factor and had a recommendatory

nature. The possibility of simultaneous increase in muscle mass and decrease in adipose tissue in trained individuals was substantiated by C. Barakat *et al.* (2020). This is consistent with the data, as body composition recomposition occurred in all groups, but the magnitude of this was greatest with the periodised method. Additional context is provided by N. Piakaew *et al.* (2025), who compared body composition, energy, and macronutrient intake of recreational bodybuilders and healthy adults. The findings are partially consistent with the results, but direct comparison is limited by the fact that nutrient intake was not a separate subject of analysis.

Anthropometric changes most clearly reflected the advantage of periodised strength-hypertrophic training: shoulder girth increased by 1.6 cm, chest girth by 2.5 cm, hip girth by 2.3 cm, while waist girth decreased by 2.9 cm. In the drop-set group, the corresponding changes were more moderate – 1.3 cm, 1.8 cm, 1.6 cm, and 1.9 cm, while with the traditional method the changes were 0.9 cm, 1.4 cm, 1.1 cm, and 1.4 cm, indicating a gradation of the effect depending on the load structure. The obtained dynamics are consistent with the conclusions of R.C. Alves *et al.* (2020), who noted that hypertrophic programmes in bodybuilding should provide not only an overall increase in muscle mass, but also a targeted load on individual muscle groups. In this context, the greater increase in the shoulder, chest, and thigh in the third group confirms the effectiveness of combining basic strength movements with auxiliary exercises aimed at local processing of body segments. The results also coincide with the positions of D. Souza *et al.* (2020), who linked the increase in muscle size and lean mass with training volume. At the same time, the obtained data clarify this position: the largest girth changes occurred not only due to volume, but when combined with higher intensity and wave-like progression. The interpretation of local changes also correlates with the approach of H. Lukaski & C. Raymond-Pope (2021), who substantiated the need for a comprehensive assessment of morphological indicators in sports. Comparison of girths with body composition data showed that the increase in peripheral parameters was not an isolated phenomenon, but was accompanied by a reduction in the central fat component. The position of A. Gonzalez *et al.* (2022) on the feasibility of using advanced strength training strategies in bodybuilding are consistent with the advantage of drop sets and periodised methods over the traditional programme. However, the best result was obtained precisely by periodisation, which indicates a greater effectiveness of the systematic alternation of strength and hypertrophic stimuli compared to an isolated increase in work density. The data of A. Falih (2025), obtained when using drop sets in young bodybuilders, confirmed the positive effect of this technique on bodybuilding indicators, but only partially coincide with the results presented. The discrepancy is that in adult trained athletes, drop sets improved girth parameters, but did not exceed periodised strength-hypertrophic training in terms of the effect on proportionality and expressiveness of the relief.

Power dynamics showed the advantage of periodised strength-hypertrophic training: the TSI increased by 57.2 kg, while the drop-set increase was 31.7 kg, and the traditional method – 29.9 kg. The most noticeable difference concerned the squat and deadlift, since these exercises depend not only on muscle volume, but also on the ability to coordinate the work of large muscle groups under high load. In the work of C.G. Vann *et al.* (2022), it was shown that high-volume and high-intensity training form different mechanisms of muscle adaptation. This explains the greater increase in strength in the third group, which regularly used a higher relative weight in basic exercises, which increased mechanical stress and neuromuscular mobilisation. In a systematic review, M. Lacio *et al.* (2021) found that different load ranges can stimulate both hypertrophy and maximum strength gains. The results presented concretise this position: the best strength effect was provided not by the isolated use of a certain repetition range, but by the combination of a strength block with a hypertrophic volume. Variable strength training, according to the conclusions of V. Andersen *et al.* (2022), contributes to the development of maximum strength and muscle power. The advantage of the third group confirms the importance of a wave-like change in intensity, which created conditions for load progression without excessive accumulation of fatigue. Data from the work by K. Keskin *et al.* (2025) on similar improvements in strength, endurance, and hypertrophy after traditional training, pre-exhaustion and drop sets with the same load volume help explain the moderate advantage of drop sets over the traditional method. In this study, drop sets did indeed produce a greater increase in total strength index than the traditional programme, but the effect remained lower than that of the periodised approach due to a smaller proportion of work with high relative weight. Adaptations of lean mass and muscle cross-section under block periodisation conditions were described by P.A. Moquin *et al.* (2021). These results strengthen the interpretation of the advantage of the periodised programme, since the increase in strength indicators in the third group was combined with the greatest increase in lean and skeletal muscle mass.

Correlation analysis showed a direct relationship between the increase in skeletal muscle mass and an increase in total strength index ($r = 0.74$; $p < 0.001$), as well as between a decrease in waist circumference and a reduction in the fat component ($r = 0.72$; $p < 0.001$). This confirmed that the formation of muscle relief was determined not by a single indicator, but by a combination of hypertrophy, improved body composition and increased strength. The relationship between body composition and strength and power was revealed in the study by G. Ben Mansour *et al.* (2021). The data obtained by the authors help to explain the identified correlations, however, the sample of students limits the direct transfer of these conclusions to bodybuilders with systematic strength training experience. Single and multi-stage drop sets were compared with traditional strength training by M. Fasihiyan *et al.* (2023), assessing muscle performance and body composition. This gives grounds to interpret drop sets as a technique capable of simultaneously influencing morphological and functional indicators, although in the results obtained the effect was inferior to the periodised approach. In a systematic review by E. Baz-Valle *et al.* (2022), the authors found that the effect of training volume on hypertrophy depends on the structure of the programme and the level of fitness. This approach explains why muscle mass gains were associated with strength progress, but could not be fully determined

by the amount of work performed alone. The acute and chronic effects of drop sets, according to the conclusions of T. Havers *et al.* (2026), depend on the protocol, training volume and comparison regime. This makes it possible to explain the positive dynamics in the drop sets group without exaggerating the effectiveness compared to the periodised programme. The findings of L. Moesgaard *et al.* (2022) are closest to the revealed pattern, which showed that periodisation can affect strength and hypertrophy even with comparable training volume. That is why the connection between the increase in skeletal muscle mass, the increase in the strength index and the better results of the periodised method can be explained not only by the volume of training, but also by the rational alternation of intensity, recovery and hypertrophic stimulus.

Comparison of the obtained data with scientific sources made it possible to clarify the place of periodised strength-hypertrophic training among the methods aimed at the formation of muscle relief. Changes in body composition, anthropometric parameters and strength training correspond to the conclusions of studies that proved the importance of intensity, volume, load variability and recovery control. The advantage of the periodised method was manifested simultaneously in the increase in the muscle component, the reduction of adipose tissue, the improvement of body proportions and the increase in strength.

Conclusions

Comparison of body composition indicators showed that all three strength training methods contributed to positive morphological dynamics, but the greatest changes were recorded after periodised strength-hypertrophic training. In this group, skeletal muscle mass increased by 2.4 kg, lean mass by 2.6 kg, and the fat component decreased by 2.3%. In the drop-set group, the corresponding changes were 1.5 kg, 1.7 kg, and 1.7%, and with the traditional hypertrophic method – 1.1 kg, 1.3 kg, and 1.1%. This indicates that the combination of strength and hypertrophic regimes provided a more pronounced body recomposition. Analysis of anthropometric parameters confirmed that the formation of muscle relief depended not only on the increase in muscle mass, but also on changes in body proportions. In the periodised training group, shoulder girth increased by 1.6 cm, chest girth by 2.5 cm, hip girth by 2.3 cm, while waist girth decreased by 2.9 cm. In the drop-set group, these changes were 1.3 cm, 1.8 cm, 1.6 cm, and 1.9 cm, respectively, and in the traditional method group, 0.9 cm, 1.4 cm, 1.1 cm, and 1.4 cm. Thus, the periodised programme provided a better combination of peripheral muscle segment development and central girth reduction. Strength training improved most significantly in the periodised strength-hypertrophic training group.

TSI increased by 57.2 kg, which exceeded the increase in the drop-set group by 25.5 kg and in the traditional method group by 27.3 kg. The greatest advantage of this technique was manifested in basic exercises that required high mechanical tension, stabilisation and coordinated work of large muscle groups. This confirmed that not only hypertrophic volume, but also the systematic inclusion of higher intensity approaches, is effective for strength gains in bodybuilders. Correlation analysis showed a relationship between morphological and strength changes. The increase in skeletal muscle mass was associated with an increase in TSI ($r = 0.74$; $p < 0.001$), and a decrease in waist circumference was associated with a decrease in the fat component ($r = 0.72$; $p < 0.001$). This proves that the formation of muscle relief was complex and was determined by a combination of hypertrophy, reduction of adipose tissue, improvement of anthropometric proportions and an increase in strength training. The limitation of the study is the formation of a sample of only men, which makes it impossible to assess the sexual characteristics of adaptation, as well as the 8-week duration of the experiment, which does not allow determining the long-term stability of morphological and strength changes. In future studies, it is advisable to involve bodybuilders of both sexes, and use a longer observation period to assess the preservation of muscle relief, compositional changes and strength indicators after several consecutive mesocycles of training.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Alves, R.C., Prestes, J., Enes, A., de Moraes, W.M.A., Trindade, T.B., de Salles, B.F., Aragon, A.A., & Souza-Junior, T.P. (2020). Training programs designed for muscle hypertrophy in bodybuilders: A narrative review. *Sports*, 8(11), article number 149. doi: 10.3390/sports8110149.

[2] Andersen, V., Prieske, O., Stien, N., Cumming, K., Solstad, T.E.J., Paulsen, G., van den Tillaare, R., Pedersen, H., & Saeterbakken, A.H. (2022). Comparing the effects of variable and traditional resistance training on maximal strength and muscle power in healthy adults: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, 25(12), 1023-1032. doi: 10.1016/j.jsams.2022.08.009.

[3] Barakat, C., Pearson, J., Escalante, G., Campbell, B., & De Souza, E.O. (2020). Body recomposition: can trained individuals build muscle and lose fat at the same time? *Strength & Conditioning Journal*, 42(5), 7-21. doi: 10.1519/SSC.0000000000000584.

[4] Baz-Valle, E., Balsalobre-Fernández, C., Alix-Fages, C., & Santos-Concejero, J. (2022). A systematic review of the effects of different resistance training volumes on muscle hypertrophy. *Journal of Human Kinetics*, 81, 199-210. doi: 10.2478/hukin-2022-0017.

[5] Ben Mansour, G., Kacem, A., Ishak, M., Grélot, L., & Ftaiti, F. (2021). The effect of body composition on strength and power in male and female students. *BMC Sports Science, Medicine and Rehabilitation*, 13, article number 150. doi: 10.1186/s13102-021-00376-z.

[6] Caha, J., Cacek, J., Ondráček, J., Králová, T., Přemysl, Š., Šiška, S., Vomáčková, K., Žák, M., & Vodička, T. (2021). Changes and differences in body composition and strength abilities of athletes in fitness and bodybuilding at different intervals of rest. *Studia Sportiva*, 15(1), 6-16. doi: 10.5817/StS2021-1-1.
[7] Chernozub, A., Manolachi, V., Tsos, A., Potop, V., Korobeynikov, G., Manolachi, V., Sherstiuk, L., Zhao, J., & Mihaila, I. (2023). Adaptive changes in bodybuilders in conditions of different energy supply modes and intensity of training load regimes using machine and free weight exercises. *PeerJ*, 11, article number e14878. doi: 10.7717/peerj.14878.
[8] Falih, A.A. (2025). The effect of proposed training units according to the dropset system on some physical and physical variables among young players in the game of bodybuilding. *University of Thi-Qar Journal for Sciences of Physical Education*, 2(3), 18-29.
[9] Fasihiyan, M., Forbes, S., Taheri, M., Lopez, J.G., Babaie, M., Dejam, B., & Nourshahi, M. (2023). The effects of a single or multi-step drop-set training compared to traditional resistance training on muscle performance and body composition. *Scientific Journal of Sport and Performance*, 2(3), 410-422. doi: 10.55860/ZMKL1980.
[10] Gonzalez, A.M., Escalante, G., Varovic, D., Schwarz, A.V., Rolnick, N., & De Souza, E.O. (2022). Advanced resistance training strategies for bodybuilding: Tools for muscle hypertrophy. *Strength & Conditioning Journal*. doi: 10.1519/SSC.0000000000000929.
[11] Graybeal, A.J., Moore, M.L., Cruz, M.R., & Tinsley, G.M. (2020). Body composition assessment in male and female bodybuilders: A 4-compartment model comparison of dual-energy X-ray absorptiometry and impedance-based devices. *The Journal of Strength & Conditioning Research*, 34(6), 1676-1689. doi: 10.1519/JSC.0000000000002831.
[12] Havers, T., Micke, F., Geisler, S., & Held, S. (2026). Acute and chronic effects of drop-set training: A meta-analysis and systematic review. *Sports Medicine-Open*, 12, article number 38. doi: 10.1186/s40798-026-01012-1.
[13] Karaulova, S.I., & Troian, A.Y. (2024). Modern methodological approaches to the systematic training of athletes specializing in bodybuilding. In *International scientific conference "Physical culture and sports as a modern priority"* (pp. 10-14). Riga: Baltija Publishing. doi: 10.30525/978-9934-26-479-5-2.
[14] Karaulova, S.I., Tyshchenko, V.O., & Troian, A.Y. (2025). Optimization of training loads of beginner athletes specializing in bodybuilding. *Scientific Journal of the Ukrainian State University Named After Mykhailo Drahomanov. Series 15*, 3K(188), 148-151. doi: 10.31392/UDU-nc.series15.2025.03k(188).31.
[15] Keskin, K., Gogus, F. N., Gunay, M., & Fujita, R. A. (2025). Equated volume load: similar improvements in muscle strength, endurance, and hypertrophy for traditional, pre-exhaustion, and drop sets in resistance training. *Sport Sciences for Health*, 21(1), 495-504. doi: 10.21203/rs.3.rs-4564565/v1.
[16] Lacio, M., Vieira, J.G., Trybulski, R., Campos, Y., Santana, D., Filho, J.E., Novaes, J., Vianna, J., & Wilk, M. (2021). Effects of resistance training performed with different loads in untrained and trained male adult individuals on maximal strength and muscle hypertrophy: A systematic review. *International Journal of Environmental Research and Public Health*, 18(21), article number 11237. doi: 10.3390/ijerph182111237.
[17] Lukaski, H., & Raymond-Pope, C.J. (2021). New frontiers of body composition in sport. *International Journal of Sports Medicine*, 42(7), 588-601. doi: 10.1055/a-1373-5881.
[18] Moesgaard, L., Beck, M.M., Christiansen, L., Aagaard, P., & Lundbye-Jensen, J. (2022). Effects of periodization on strength and muscle hypertrophy in volume-equated resistance training programs: A systematic review and meta-analysis. *Sports Medicine*, 52, 1647-1666. doi: 10.1007/s40279-021-01636-1.
[19] Moquin, P.A., Wetmore, A.B., Carroll, K.M., Fry, A.C., Hornsby, W.G., & Stone, M.H. (2021). Lean body mass and muscle cross-sectional area adaptations among college age males with different strength levels across 11 weeks of block periodized programmed resistance training. *International Journal of Environmental Research and Public Health*, 18(9), article number 4735. doi: 10.3390/ijerph18094735.
[20] Mykhaliuk, Y., Horokhovskyi, Y., Bosenko, A., Khoroshukha, M., & Pavliuk, O. (2025). Dynamic monitoring of functional status in athletes performing physical loads in vertical and horizontal planes with equivalent energy supply for muscle training. *Physical Rehabilitation and Recreational Health Technologies*, 10(3), 162-172. doi: 10.15391/prrht.2025-10(3).03.
[21] Piakaew, N., Subprasert, V., Lutthapinun, N., Saitong, A., Chinapong, S., & Nokkaew, N. (2025). A comparison of body composition, energy and macronutrient intakes between recreational bodybuilders and healthy adults. *Journal of Exercise Physiology Online*, 28(3).
[22] Piven, O.B., Orlov, A.A., & Symchenko, A.V. (2023). Optimizing competitive period training for qualified bodybuilders: An analysis of muscle mass development and physique enhancement. *Scientific Journal of the Ukrainian State University Named After Mykhailo Drahomanov. Series 15*, 9(169), 121-123. doi: 10.31392/NPU-nc.series15.2023.9(169).25.
[23] Podrigalo, L., Tymchenko, K., Perevoznyk, V., Semeniv, B., Paievskyi, V., & Halashko, O. (2025). Scientific support for strength sports: Analysis of scientific resources from the Web of Science Core Collection. *Pedagogy of Physical Culture and Sports*, 29(1), 44-61. doi: 10.15561/26649837.2025.0106.
[24] Potop, V., Manolachi, V., Chernozub, A., Kozin, V., Syvokhop, E., Spivak, A., Sharodi, V., & Jie, Z. (2023). Changes in circumference sizes of bodybuilders using machine and free weight exercises in combination with different load regimes. *Health, Sport, Rehabilitation*, 9(2), 74-85. doi: 10.34142/HSR.2023.09.02.06.
[25] Schoenfeld, B.J., *et al.* (2020). Alterations in body composition, resting metabolic rate, muscular strength, and eating behavior in response to natural bodybuilding competition preparation: A case study. *Journal of Strength and Conditioning Research*, 34(11), 3124-3138. doi: 10.1519/JSC.0000000000003816.

[26] Sødal, L.K., Kristiansen, E., Larsen, S., & van den Tillaar, R. (2023). Effects of drop sets on skeletal muscle hypertrophy: A systematic review and meta-analysis. *Sports Medicine-Open*, 9(1), article number 66. doi: 10.1186/s40798-023-00620-5.
[27] Souza, D., Barbalho, M., & Gentil, P. (2020). The impact of resistance training volume on muscle size and lean body mass: To infinity and beyond? *Human Movement*, 21(4), 18-29. doi: 10.5114/hm.2020.94199.
[28] The Declaration of Helsinki. (2024). Retrieved from https://www.wma.net/policies-post/wma-declaration-of-helsinki/.
[29] Vann, C.G., *et al.* (2022). Effects of high-volume versus high-load resistance training on skeletal muscle growth and molecular adaptations. *Frontiers in Physiology*, 13, article number 857555. doi: 10.3389/fphys.2022.857555.
[30] Varović, D., Žganjer, K., Vuk, S., & Schoenfeld, B.J. (2021). Drop-set training elicits differential increases in non-uniform hypertrophy of the quadriceps in leg extension exercise. *Sports*, 9(9), article number 119. doi: 10.3390/sports9090119.

Порівняльний аналіз ефективності різних методик силового тренування для формування м'язового рельєфу у спортсменів-бодібілдерів

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Анотація. Метою дослідження було визначити, як різні варіанти організації силових навантажень впливають на розвиток м'язової маси, зміну композиції тіла та виразність рельєфу у спортсменів-бодібілдерів. Дослідження проведено на базі Уманського національного університету (Україна) з 20 жовтня до 12 грудня 2025 року за участю 66 спортсменів-бодібілдерів чоловічої статі, які виконували 8-тижневі програми традиційного гіпертрофічного тренування, дроп-сетів і періодизованого силово-гіпертрофічного тренування, а оцінювання їх ефективності здійснювали за допомогою педагогічного експерименту, біоімпедансного аналізу, антропометрії, тестування одноповторного максимуму, розрахунку сумарного силового індексу та статистичного аналізу. Найвиразніші зміни композиції тіла відбулися у групі періодизованого силово-гіпертрофічного тренування: скелетна м'язова маса зросла на 2,4 кг, безжирова маса – на 2,6 кг, а частка жирової тканини зменшилася на 2,3 %, що пояснюється поєднанням високого механічного напруження в базових вправах із достатнім гіпертрофічним обсягом у допоміжних рухах. Антропометричні показники підтвердили покращення рельєфу: обхват плеча збільшився на 1,6 см, грудної клітки – на 2,5 см, стегна – на 2,3 см, тоді як талія зменшилася на 2,9 см, що відображає покращення пропорцій тілобудови. Сумарний силовий індекс зріс на 57,2 кг проти 31,7 кг у групі дроп-сетів і 29,9 кг у групі традиційної методики, що підтверджує перевагу періодизації для розвитку максимальної сили. Кореляційний аналіз показав зв'язок приросту скелетної м'язової маси із силовим індексом ($r = 0,74$), а зменшення талії – зі зниженням жирової тканини ($r = 0,72$), що доводить взаємозалежність морфологічних і функціональних змін. Отже, періодизоване силово-гіпертрофічне тренування найефективніше поєднало приріст м'язової маси, зниження жирового компонента, покращення пропорцій і підвищення сили у бодібілдерів. Результати можуть бути використані тренерами з бодібілдингу, фахівцями з фізичної культури і спорту та спортсменами для планування тренувальних програм, спрямованих на формування м'язового рельєфу й контроль композиції тіла

Ключові слова: композиція тіла; безжирова маса; антропометричні параметри; адаптація; гіпертрофія; морфологічні зміни; дроп-сет

THEORY and PRACTICE
of Physical Culture and Sports

https://tppcs.com.ua/
Vol. 5, No. 1, 2026

Received: 03.12.2025.Revised: 03.04.2026. Accepted: 12.05.2026. Published: 26.06.2026.

ISSN 2786-6432
e-ISSN 2786-6424

UDC 796.422.012.1
DOI: 10.69587/tppcs/1.2026.96

The influence of anthropometric characteristics on the performance of track-and-field athletes in running events

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Abstract. The purpose of the study was to clarify how the anthropometric characteristics of track-and-field athletes are related to performance in sprint, middle-distance, and long-distance running. The study was conducted on 6-10 April 2025 at the Hryhorii Skovoroda University in Pereiaslav, with the participation of 90 male track-and-field athletes aged 18-24 years, divided into sprint, middle-distance, and long-distance groups. Anthropometric indicators, control running results, and statistical relationships between physical parameters and sports performance were assessed. The results showed distance-specific features of anthropometric profile, running speed, correlation patterns, and regression predictors. Sprinters had higher body mass, single-leg thigh circumference, and muscle mass percentage: 82.4 ± 6.8 kg, 62.8 ± 3.4 cm, and 47.8 ± 3.0%, which reflected the predominance of the muscle-strength component over short distances. Among long-distance runners, lower body mass, body mass index, and fat mass percentage – 70.8 ± 5.7 kg, 22.6 ± 1.3 kg/m², and 9.8 ± 1.8% – were associated with greater economy in prolonged running. Mean speed was 8.63 ± 0.41, 5.71 ± 0.32, and 4.62 ± 0.28 m/s in the sprint, middle-distance, and long-distance groups, respectively. The correlations linked sprint speed with muscle mass (r = 0.62), whereas in long-distance runners, speed had an inverse association with fat mass (r = -0.56). The regression models explained 51%, 46%, and 49% of speed variability, confirming the different role of anthropometric factors in each running specialisation. The results confirmed that the anthropometric determinants of performance differ by running specialisation: muscle-strength parameters predominate in sprinting, whereas lower fat mass and a more economical body-build profile are more important over long distances. In practical terms, these data may be used by coaches, athletics teachers, and sports selection specialists to refine distance specialisation and individualise the training process

Keywords: distance specialisation; sprint; body mass index; body build; long-distance runners; speed-strength realisation; endurance

Introduction

Track and field includes running events in which sports performance depends on a specific combination of morphological, functional, and biomechanical prerequisites. In sprint, middle-distance, and long-distance running, isolated physical parameters matter less than their interrelationship: height, body mass, lower-limb length, body mass index (BMI), and the proportions of muscle and fat components. Assessment of these characteristics helps to substantiate sports specialisation more precisely, predict performance, and select training-load parameters in line with the individual morphological profile of the athlete. Insufficient detail in anthropometric criteria for running events complicates the selection of optimal specialisation, as physical parameters that support success in sprinting are not always advantageous in middle-distance or long-distance running. This increases the likelihood of errors in sports selection, inaccurate prediction of competitive potential, and the choice of training loads that do not fully match the morphological and functional capacities of the track-and-field athlete.

Suggested Citation: Yuzkovets, I., & Ruban, V. (2026). The influence of anthropometric characteristics on the performance of track-and-field athletes in running events. *Theory and Practice of Physical Culture and Sports*, 5(1), 96-108. doi: 10.69587/tppcs/1.2026.96.

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Performance in track-and-field running events develops through the interaction of technical preparedness, functional reserves, motor qualities, and the morphological characteristics of the athlete; therefore, anthropometric parameters should be interpreted together with biomechanical, functional, and training-related factors of sports working capacity. I. Novikova *et al.* (2025) described the influence of athletics on the physical condition of a person, linking it with the development of endurance, coordination, speed abilities, and general functional readiness. This approach emphasised that running events depend not only on the amount of training work but also on the correspondence between physical development and the demands of a specific type of load. A. Kolot *et al.* (2025) substantiated the importance of technical preparation in the system of sports improvement for track-and-field athletes. Within this approach, anthropometric characteristics may be treated as factors affecting running-stride length, movement amplitude, the spatio-temporal organisation of running, and the effectiveness with which muscular effort is realised. In the study by I. Ivanyshyn *et al.* (2024), spirographic indicators of functional reserves in veteran track-and-field athletes specified the role of the respiratory system in maintaining working capacity during running load. The results confirmed that the morphological profile of an athlete should be assessed together with functional capacity, since running performance depends on the coherence of body build, technique, and physiological support for movement.

The anthropometric profile of an athlete reflects the morphological prerequisites for running work, because height, body mass, limb proportions, BMI, and the ratio of muscle to fat components determine the mechanical and energetic conditions of movement along a distance. O.S. Polianska *et al.* (2025) substantiated the value of anthropometric assessment for predicting sports performance by treating physical parameters as a basis for determining the potential of an athlete and their correspondence to the requirements of the chosen sport. The researchers noted that anthropometry is used not only to describe the external characteristics of an athlete but also to explain the relationship between body build, motor capacity, and the expected competitive result. N.V. Vdovenko *et al.* (2024) addressed the features of the fat component in qualified athletes of different specialisations and showed the variability of body composition according to the type of sports load. The work established that, for representatives of cyclic events, assessment of fat mass is linked with determining the ratio between active and inactive body mass, since excess fat may increase the energetic cost of motor work. A. Stachoń *et al.* (2023) showed that distance specialisation among runners is accompanied by differences in morphology and body composition. This supports the need for separate assessment of sprinters, middle-distance runners, and long-distance runners because the same anthropometric parameters may have different functional significance depending on the type of running work.

Distance specialisation in running imposes different requirements on body build, strength potential, movement economy, and the ability to maintain a given load intensity; accordingly, anthropometric characteristics need to be interpreted with reference to the structure of the specific distance. R. Pavlovic *et al.* (2022) analysed the anthropometric parameters of elite sprinters and determined the predictive significance of height and body mass for sports results. Their data confirmed that, in sprinting, morphological characteristics are meaningful for performance only in combination with running technique, strength capacity, and the ability to realise high speed over a short section. G.A. Christou *et al.* (2021) addressed the anthropometric, cardiorespiratory, and haematological determinants of marathon performance. The authors indicated that achievements in long-distance running depend not on an isolated body-build indicator, but rather on a combination of morphological parameters, cardiovascular capacity, oxygen-transport potential, and general endurance. L.A. Peyré-Tartaruga *et al.* (2024) treated biomechanical, physiological, and anthropometric predictors as interrelated factors in the performance of recreational runners. The researchers demonstrated that running effectiveness arises from the interaction of morphological profile, functional capacity, and biomechanical movement characteristics. Therefore, anthropometric assessment should be combined with analysis of technique and physiological readiness. P.T. Nikolaidis & B. Knechtle (2024) summarised the profile of marathon runners and predictors of long-distance performance. Their review confirmed that long-distance performance is associated with lower body mass, optimal BMI, a smaller fat component, high aerobic productivity, and running economy, which differentiates the morphofunctional demands of long distances from sprint specialisation.

The character of the relationship between anthropometric characteristics and performance among track-and-field athletes of different running specialisations remains insufficiently clarified. The purpose of the study was to substantiate the role of anthropometric characteristics in forming the performance of track-and-field athletes in running events with different distance orientations. The following objectives were defined: to characterise the anthropometric and performance indicators of track-and-field athletes of different running specialisations; to establish statistical relationships between the physical parameters of athletes and performance in sprint, middle-distance, and long-distance running; and to determine the anthropometric characteristics with the greatest predictive significance for sports success in separate groups of running events.

Materials and Methods

Design and study setting

The work was conducted as a comparative correlational study with a single recording of anthropometric and performance indicators in track-and-field athletes. The study setting was the Faculty of Physical Education, Sport and Health of the Hryhorii Skovoroda University in Pereiaslav. The choice of this setting was justified by its direct relevance to athletics training, sports training, and assessment of athletes' performance in running events. It was also determined by the availability of training conditions, sports equipment, methodological support, and the possibility of recording anthropometric and running indicators. The study period lasted from 6 to 10 April 2025. It was selected because it preceded the spring-summer competitive period, when control results in running events reflect the current level of special preparedness among track-and-field athletes. The five-day period was sufficient to record

the anthropometric parameters and running results of all participants.

Characteristics of the study sample

The sample included 90 male track-and-field athletes who were in years 1-4 of the Faculty of Physical Education, Sport and Health at the Hryhorii Skovoroda University in Pereiaslav. The participants were aged 18-24 years, and their mean age was 20.8 ± 1.7 years. A single-sex sample was chosen to reduce the influence of sex differences in body composition, strength capacity, and running results on the assessment of the relationship between anthropometric parameters and performance. The sample was divided into three equal groups, 30 participants each, by distance specialisation: sprinters (100 and 200 m), middle-distance runners (800 and 1,500 m), and long-distance runners (5,000 and 10,000 m), 30 participants. The sample was purposive. It was formed by distributing information about the study among students of the athletics department, members of sports groups, and representatives of the training sections of the faculty.

The inclusion criteria were: study in years 1-4 at the study setting; age 18-24 years; specialisation in track-and-field running events; membership of one of the distance-specialisation groups; sports experience of at least 2 years; regular participation in the training process; complete anthropometric indicators and a control result for the main distance; absence of medical restrictions on running loads; and voluntary consent to participate. The exclusion criteria were: mixed or undefined running specialisation; involvement in non-running track-and-field events; irregular training during the preceding three months; acute musculoskeletal injuries; abrupt body-mass change during the preceding three months; incomplete assessment procedure; or withdrawal from participation. No participants left the sample before the completion of the study, so group sizes remained equal, and the analysis was carried out using the full set of anthropometric and performance indicators.

Procedure for data collection and recording

Data were collected in two locations: anthropometric indicators were recorded in a medical room designated for standardised measurements, and control running results were recorded on an athletics track designated for control trials. The procedure was conducted by a department teacher and the coach of the training group, who supervised a uniform measurement procedure, correct recording of indicators, and allocation of athletes according to distance specialisation. Anthropometric measurements were conducted individually in the first half of the day, from 9:00 to 12:00, before the main training session and after a 2-3-hour period without food. Participants also avoided intensive physical load on the previous day, which reduced the influence of fatigue, body mass fluctuations, food intake, and hydration status on the assessment results.

Age, year of study, sports experience, main running distance, and specialisation group were recorded first. Height, body mass, lower-limb length, thigh circumference, fat mass percentage, and muscle mass percentage were then measured. Height was measured with a stadiometer in a standing position without shoes, accurate to 0.5 cm, and body mass was measured using Seca 876 electronic medical scales (Seca GmbH & Co. kg, Germany), in light sports clothing and without shoes, accurate to 0.1 kg. Lower-limb length was measured with an anthropometric tape from the anterior superior iliac spine to the floor in a standing position, and thigh circumference was measured at the level of the greatest circumference, accurate to 0.1 cm. Body-composition indicators were recorded by bioelectrical impedance analysis using a Tanita BC-545N body composition analyser (Tanita Corporation, Japan); before measurement, participants removed metal objects and maintained the body position specified in the device instructions. BMI was calculated using the following formula:

$$BMI = \frac{m}{h^2}, \quad (1)$$

where BMI – body mass index, kg/m^2; m – body mass of the athlete, kg; h – height of the athlete, m. The ratio of lower-limb length to height (LLL/H) was calculated using the following formula:

$$LLL/H = \frac{L_{LL}}{h} \times 100, \quad (2)$$

where LLL/H – ratio of lower-limb length to height, %; L_{LL} – lower-limb length, cm; h – height of the athlete, cm. The resulting indicator reflected the proportion of lower-limb length within total body length and was used to assess body-build proportionality in runners. The anthropometric assessment procedure was identical for the three distance-specialisation groups: sprint, middle-distance running, and long-distance running, which ensured comparability of indicators between groups. The anthropometric indicators obtained were used to characterise mass-height parameters, body-build proportionality, and body composition in track-and-field athletes of different distance specialisations.

The differences concerned the recording of sports performance: in the sprint group, the time for 100 or 200 m was recorded; in the middle-distance group – for 800 or 1,500 m, and in the long-distance group – for 5,000 or 10,000 m. Distances followed the standard markings of the athletics track, and time to cover the distance was recorded using a Casio HS-80TW-1EF electronic stopwatch (Casio Computer Co., Ltd., Japan), accurate to 0.01 s. Control runs were conducted after a standard warm-up under the supervision of the coach; one result for the main distance was recorded for each participant. Mean running speed was calculated to compare results across different distances using the following formula:

$$V = \frac{S}{t}, \quad (3)$$

where V – mean running speed, m/s; S – distance length, m; t – time taken to cover the distance, s. A standardised performance index was calculated for additional comparison of athletes from different distance specialisations using formula:

$$PI = \frac{T_{max} - T_i}{T_{max} - T_{min}}, \quad (4)$$

where PI – standardised performance index, arbitrary units; T_i – individual time of the athlete over the main distance, s; T_{max} – greatest time in the corresponding distance group,

s; T_{min} – shortest time in the corresponding distance group, s. The index ranged from 0 to 1, with a higher value corresponding to a better result within the relevant distance group. After the measurement, the data were entered into a consolidated electronic spreadsheet using an individual participant code and without personal information. The control-run result, mean running speed, and standardised performance index were treated as sports-performance indicators, which allowed comparing the physical parameters of athletes with their results in sprint, middle-distance, and long-distance running.

Methods of statistical analysis

Statistical analysis was conducted after checking data completeness and coding participants by distance-specialisation group. Quantitative data were summarised using descriptive statistics, including the mean level of the indicator, standard deviation, and the minimum and maximum recorded values. The distribution of variables was checked using the Shapiro-Wilk test. One-way analysis of variance (ANOVA) was used to compare anthropometric and performance indicators among the three groups when the data were normally distributed. When statistically significant inter-group differences were present, post-hoc pairwise comparisons with Bonferroni correction were performed. The relationship between anthropometric parameters and sports performance was determined using correlation analysis. Pearson's coefficient was used for normally distributed variables, and Spearman's coefficient – for variables with a non-normal distribution. Correlation strength was interpreted as follows: below 0.30 – weak; 0.30-0.49 – moderate; 0.50-0.69 – pronounced; and 0.70 or above – strong.

The predictive significance of anthropometric parameters for sports performance was assessed using multiple linear regression. Mean running speed was the dependent variable, while height, body mass, BMI, lower-limb length, thigh circumference, fat mass percentage, muscle mass percentage, and LLL/H – the independent variables. Separate regression models were constructed for the whole sample and for the sprint, middle-distance, and long-distance groups. Results were treated as statistically significant at $p < 0.05$. IBM SPSS Statistics 26.0 (USA) was used for statistical processing of the collected dataset, and the results were interpreted with reference to correlation coefficients, standardised β coefficients, and the explained variance R^2.

Ethical aspects and study limitations

The study was organised in accordance with the basic ethical principles of voluntary participation, informed consent, confidentiality, and risk minimisation, consistent with the provisions of The Declaration of Helsinki (2024). Participants were informed in advance about the purpose, measurement procedures, and use of data in a summarised form. Personal data were not entered into the final database, and each participant was assigned an individual code. The procedures did not involve medical intervention, the use of medicines, or experimental influence on the body of the athletes. One limitation of the study was its cross-sectional assessment, which did not allow changes in anthropometric characteristics and sports performance to be traced across a training cycle. The sample also included only male track-and-field athletes of student age, so the results should not be directly generalised to female athletes, juniors, or track-and-field athletes from other age and qualification groups.

Results

Anthropometric profile of track-and-field athletes of different distance specialisations

The anthropometric profile of male track-and-field athletes was assessed according to distance specialisation. Comparison of the three groups showed pronounced inter-group differences: sprinters had higher values for body mass, BMI, thigh circumference, and muscle mass; long-distance runners had lower mass-height and composition indicators; and middle-distance runners occupied an intermediate position for most parameters. This structure of results reflected different morphological correspondence between athletes and the demands of short, middle, and long distances. Descriptive statistics for anthropometric indicators are presented in Table 1. BMI was calculated using formula (1), and LLL/H was calculated using formula (2).

Table 1. Anthropometric indicators of track-and-field athletes of different distance specialisations, M ± SD

Indicator	Sprint, n = 30	Middle distances, n = 30	Long distances, n = 30
Height, cm	181.2 ± 5.6	179.4 ± 5.3	176.8 ± 5.1
Body mass, kg	82.4 ± 6.8	75.6 ± 6.1	70.8 ± 5.7
BMI, kg/m^2	25.1 ± 1.6	23.5 ± 1.4	22.6 ± 1.3
Lower-limb length, cm	94.1 ± 4.0	92.7 ± 3.8	91.1 ± 3.6
LLL/H, %	51.9 ± 1.5	51.7 ± 1.4	51.5 ± 1.4
Single-leg thigh circumference, cm	62.8 ± 3.4	59.6 ± 3.1	56.4 ± 2.9
Fat mass percentage, %	12.2 ± 2.3	11.0 ± 2.0	9.8 ± 1.8
Muscle mass percentage, %	47.8 ± 3.0	45.9 ± 2.8	44.2 ± 2.6

Source: compiled by the authors

According to Table 1, sprinters had the highest mean values for body mass, BMI, single-leg thigh circumference, and muscle mass percentage. Body mass in this group was 82.4 ± 6.8 kg, BMI was 25.1 ± 1.6 kg/m^2, single-leg thigh circumference was 62.8 ± 3.4 cm, and muscle mass percentage was 47.8 ± 3.0%. This anthropometric profile reflected the specificity of short distances, where performance depends on the ability of an athlete to develop high mechanical power quickly, execute the start acceleration effectively, and maintain maximal speed over a short section. Higher body mass in sprinters should not be interpreted here as an unfavourable characteristic, as it was combined with a larger muscle component and a greater thigh circumference. This points to more pronounced development of the lower-limb

muscles, associated with push-off force, stride length, and the ability to generate explosive strength.

Middle-distance runners occupied an intermediate position between sprinters and long-distance runners for most indicators. Their body mass was 75.6 ± 6.1 kg, BMI – 23.5 ± 1.4 kg/m^2, single-leg thigh circumference – 59.6 ± 3.1 cm, and muscle mass percentage – 45.9 ± 2.8%. This profile reflected the mixed nature of the load in 800 and 1,500 m running, where the athlete has to combine sufficient muscular power with endurance and movement economy. Excessive increases in body mass or circumference indicators may raise the energetic cost of running, whereas insufficient development of the muscle component may restrict the ability to maintain high intensity over the distance. The mean values in this group therefore characterise a compromise morphological profile, combining prerequisites for speed work and sustained pace maintenance.

Long-distance runners had lower mean values for body mass, BMI, single-leg thigh circumference, fat mass percentage, and muscle mass percentage than the other groups. Body mass in this group was 70.8 ± 5.7 kg, BMI – 22.6 ± 1.3 kg/m^2, single-leg thigh circumference – 56.4 ± 2.9 cm, and fat mass percentage – 9.8 ± 1.8%. This profile does not imply insufficient physical development; rather, it reflects another morphological suitability for long-distance running. Over prolonged distances, lower body mass and a smaller fat component may reduce the energetic cost of movement, minimise mechanical load on the musculoskeletal system, and help maintain a stable pace. However, preservation of a sufficient muscle mass percentage in this group indicates that endurance specialisation does not require minimisation of the muscle component but its optimal level for prolonged cyclic work.

LLL/H was similar in the three groups: 51.9 ± 1.5% in sprinters, 51.7 ± 1.4% in middle-distance runners, and 51.5 ± 1.4% in long-distance runners. This demonstrates that relative lower-limb length was not the leading marker of inter-group differentiation within this sample. Absolute lower-limb length was slightly greater in sprinters, but this difference corresponded to their higher mean height. Thus, distance-specific features of the anthropometric profile were expressed through body mass, BMI, single-leg thigh circumference, and the ratio of muscle and fat components, rather than through sharply pronounced differences in lower-limb proportionality.

The results show that the anthropometric profile of track-and-field athletes differs according to distance specialisation. Sprinters had higher mass-height indicators, greater single-leg thigh circumference, and a higher muscle mass percentage, reflecting the predominance of speed-strength demands over short distances. Middle-distance runners had intermediate values for most parameters beacuse this specialisation combines the need for muscular power with the ability to sustain an intensive load. Long-distance runners had lower body mass, lower BMI, and a smaller fat mass percentage, which corresponds to the demands of prolonged cyclic work and reduced energetic cost of running.

Sports performance of track-and-field athletes in control running trials

The control running trials recorded differences in performance among track-and-field athletes of different distance specialisations. The highest mean running speed was characteristic of sprinters, lower values were observed in middle-distance runners, and the lowest values were recorded in the long-distance group. This structure reflected the different character of competitive load: short distances require maximal speed realisation, middle distances combine speed and endurance, and long distances depend on the ability to maintain a stable pace over a long period. For correct comparison of the groups, Table 2 presents not only the time to cover the main distance, but also mean running speed, calculated using formula (3), and the standardised performance index, calculated using formula (4).

Table 2. Sports performance indicators of track-and-field athletes in control running trials, M ± SD

Indicator	Sprint, n = 30	Middle distances, n = 30	Long distances, n = 30	p
Main distance	100/200 m	800/1,500 m	5,000/10,000 m	-
Time to cover the distance, s	18.9 ± 7.2	267.4 ± 89.6	2,178.5 ± 612.7	-
Mean running speed, m/s	8.63 ± 0.41	5.71 ± 0.32	4.62 ± 0.28	<0.001
Standardised performance index, arbitrary units	0.71 ± 0.12	0.64 ± 0.11	0.58 ± 0.10	0.004

Note: the time to cover the distance is presented as a characteristic of the result within the relevant group; direct inter-group comparison of absolute time was not performed because the distances differed; inter-group comparison was performed for mean running speed and the standardised performance index

Source: compiled by the authors

The data in Table 2 show that the highest mean speed was recorded in sprinters and was 8.63 ± 0.41 m/s. This result reflects the specificity of short distances, where start acceleration, high movement frequency, push-off power, and the ability to maintain maximal or near-maximal speed for a short time are of primary importance. However, this indicator should not be interpreted as a higher general level of preparedness compared with the other groups, since sprint performance is formed under short-duration load with a predominance of the speed-strength component. The high mean speed in this group characterised a specific type of competitive realisation inherent in short distances rather than a universal advantage.

In middle-distance runners, mean speed was 5.71 ± 0.32 m/s, which was lower than in sprinters but higher than in long-distance runners. This indicator reflected the intermediate nature of 800 and 1,500 m running, where the result depended on a combination of speed capacity, strength endurance, pace stability, and resistance to fatigue. Unlike sprinting, high start speed or maximal speed alone

is not sufficient in this group, as the athlete must maintain movement intensity over a longer period. Mean speed in middle-distance runners represented a balance between the power of motor actions and the ability to maintain the pace.

In the long-distance group, mean speed was 4.62 ± 0.28 m/s. The lower value of this indicator was expected since covering 5,000 and 10,000 m involves longer work, a predominance of aerobic energy supply, and the need to distribute effort rationally over the distance. For long-distance runners, performance is determined not by achieving maximal speed but by the ability to maintain a stable pace, preserve movement economy, and avoid a sharp decrease in working capacity at the end of the distance. In this context, lower mean speed does not indicate lower sports preparedness but reflects another mechanism of achieving results, associated with endurance and functional stability (Hayes & Gordon, 2021).

Mean running speed differed according to the distance specialisation of the athletes, as confirmed by the statistical significance level of $p < 0.001$. This shows that the speed component of performance depended substantially on distance specialisation and on the structure of the running load. Statistically significant differences were also recorded for the standardised performance index ($p = 0.004$). The highest mean value of this index was observed in sprinters, the intermediate value in middle-distance runners, and the lowest value in long-distance runners. This gradation may be associated with the fact that, over short distances, performance depends more directly on morphological and speed-strength parameters, whereas over long distances, pace, tactics, movement economy, aerobic productivity, and resistance to prolonged load are also important.

The results show that each group had its own sports-performance profile. Sprinters had the highest mean speed, which corresponds to the demands of short-duration speed-strength work. Middle-distance runners demonstrated intermediate values reflecting the combination of speed and endurance. Long-distance runners had lower mean speed, but this feature corresponds to the specificity of prolonged cyclic load, where maintaining pace and economising motor activity are decisive. Therefore, sports performance in control trials has pronounced distance-specific features and cannot be assessed only by the absolute time taken to cover the distance.

Correlations between anthropometric parameters and performance

Correlation analysis showed different structures of association between anthropometric parameters and mean running speed in groups with different distance specialisations. In sprinters, performance was most closely associated with indicators of the muscle component and lower-limb parameters, whereas in long-distance runners, stronger inverse relationships were recorded for body mass, BMI, and fat mass percentage. In the middle-distance group, the pattern of relationships was intermediate, with relevance for both muscle mass and indicators reflecting the energetic cost of running. Table 3 systematises the correlations between anthropometric parameters and mean running speed.

Table 3. SCorrelations between anthropometric indicators and mean running speed, r

Indicator	Sprint, n = 30	Middle distances, n = 30	Long distances, n = 30	Entire sample, n = 90
Height	0.38*	0.21	0.18	0.29*
Body mass	0.31	-0.36*	-0.48**	-0.22
BMI	0.27	-0.41*	-0.52**	-0.31*
Lower-limb length	0.46**	0.32*	0.24	0.35**
LLL/H	0.34*	0.28	0.19	0.27*
Single-leg thigh circumference	0.58**	0.39*	-0.33*	0.18
Fat mass percentage	-0.44**	-0.49**	-0.56**	-0.51**
Muscle mass percentage	0.62**	0.45**	0.29	0.48**

Note: *$p < 0.05$; **$p < 0.01$; positive r values reflect a direct relationship between the indicator and mean running speed, while negative – an inverse relationship

Source: compiled by the authors

In the sprint group, the closest relationships with mean running speed were recorded for muscle mass percentage ($r = 0.62$; $p < 0.01$), single-leg thigh circumference ($r = 0.58$; $p < 0.01$), and lower-limb length ($r = 0.46$; $p < 0.01$). This indicates that sprint performance was more closely linked with indicators characterising the muscle component and biomechanical prerequisites for high-speed running. Higher muscle mass percentage and greater single-leg thigh circumference may reflect better conditions for push-off force, start acceleration, and maintenance of high movement frequency. The positive relationship with lower-limb length also has a functional explanation – this parameter may affect the spatial structure of the running stride. Fat mass percentage had an inverse relationship with speed ($r = -0.44$; $p < 0.01$), which corresponds to lower speed realisation when inactive body mass increases.

In middle-distance runners, the correlation structure was more balanced. The most pronounced relationships were recorded between mean speed and fat mass percentage ($r = -0.49$; $p < 0.01$), muscle mass percentage ($r = 0.45$; $p < 0.01$), BMI ($r = -0.41$; $p < 0.05$), single-leg thigh circumference ($r = 0.39$; $p < 0.05$), and body mass ($r = -0.36$; $p < 0.05$). This distribution of correlations shows that performance in 800 and 1,500 m running was associated with the relationship between body mass, muscle mass, and fat component, in addition to the development of the muscle component. The positive relationship of muscle mass and thigh circumference with speed reflected the importance of

strength endurance and the ability to maintain an intensive pace. By contrast, the inverse relationships with body mass, BMI, and fat mass showed that excessive mass-height parameters may increase the energetic cost of movement and reduce running effectiveness over middle distances.

In long-distance runners, the strongest inverse correlations with speed were recorded for fat mass percentage ($r = -0.56$; $p < 0.01$), BMI ($r = -0.52$; $p < 0.01$), and body mass ($r = -0.48$; $p < 0.01$). This highlights that performance among long-distance runners was primarily linked with a lighter mass-height profile and a lower proportion of inactive body mass. In prolonged running, excess mass increases mechanical load on the musculoskeletal system, raises the energetic cost of movement, and may reduce movement economy. Single-leg thigh circumference had a moderate inverse relationship with speed ($r = -0.33$; $p < 0.05$), which differentiated this group from sprinters and middle-distance runners. This suggests that, for long distances, an excessively pronounced circumference-related muscle component of the lower limbs is not always associated with better performance since additional mass may increase energy expenditure during prolonged cyclic work.

For the whole sample, the most stable relationships with mean running speed were recorded for fat mass percentage ($r = -0.51$; $p < 0.01$), muscle mass percentage ($r = 0.48$; $p < 0.01$), lower-limb length ($r = 0.35$; $p < 0.01$), and BMI ($r = -0.31$; $p < 0.05$). The general pattern was that a higher muscle component and greater lower-limb length were linked with better speed realisation, whereas a larger fat mass percentage and higher BMI had inverse relationships with performance. However, the general correlations did not fully reflect the specificity of separate distances because the same anthropometric indicator had different functional significance in sprint, middle-distance, and long-distance running. For example, single-leg thigh circumference correlated directly with speed in sprinters but inversely in long-distance runners, confirming that the role of anthropometric factors depends on the type of competitive load.

Thus, correlation analysis determined that the relationship between anthropometric parameters and sports performance had pronounced distance-specific features. In sprinting, performance was most strongly associated with muscle mass, single-leg thigh circumference, and lower-limb length. In middle-distance running, the leading feature was a balanced relationship between the muscle component, body mass, and a low fat mass percentage. In long-distance running, better results were linked with lower body mass, lower BMI, and a smaller fat component. Anthropometric characteristics did not have a universal influence on performance. Their role changed according to the distance specialisation of the track-and-field athletes.

Anthropometric predictors of performance in running events

Regression analysis established that the anthropometric characteristics associated with mean running speed differed according to distance specialisation. In sprinters, performance was explained mainly by indicators of the muscle component and lower-limb parameters; in middle-distance runners – by a combination of muscle and fat mass with BMI; and in long-distance runners – by lower fat mass percentage, BMI, and lower-limb proportionality. Summary results of the multiple linear regression models are presented in Table 4.

Table 4. Regression models of anthropometric predictors of mean running speed

Group	Predictor	β	p	Model R^2
Sprint, n = 30	Muscle mass percentage, %	0.42	0.004	0.51
	Single-leg thigh circumference, cm	0.34	0.012	
	Lower-limb length, cm	0.27	0.041	
Middle distances, n = 30	Fat mass percentage, %	-0.39	0.007	0.46
	Muscle mass percentage, %	0.31	0.021	
	BMI, kg/m^2	-0.26	0.048	
Long distances, n = 30	Fat mass percentage, %	-0.44	0.003	0.49
	BMI, kg/m^2	-0.33	0.014	
	Body mass, kg	-0.28	0.039	

Note: β – standardised regression coefficient; R2 – proportion of explained variance in mean running speed; the table presents statistically significant predictors

Source: compiled by the authors

In the sprint group, the model explained 51% of the variability in mean running speed. Muscle mass percentage made the largest positive contribution ($\beta = 0.42$; $p = 0.004$), indicating a relationship between the development of the active muscle component and the capacity for speed-strength realisation. Single-leg thigh circumference also retained an independent statistical relationship with performance ($\beta = 0.34$; $p = 0.012$), reflecting the role of lower-limb muscular development in forming push-off force, start acceleration, and maintenance of high movement frequency. Lower-limb length had a weaker but statistically significant contribution ($\beta = 0.27$; $p = 0.041$), which may be associated with biomechanical prerequisites for running-stride length.

In the middle-distance group, the regression model explained 46% of the variability in mean speed. The most pronounced inverse relationship was recorded for fat mass percentage ($\beta = -0.39$; $p = 0.007$), exhibiting lower performance with a higher proportion of inactive body mass. Muscle mass percentage had a positive relationship with mean speed ($\beta = 0.31$; $p = 0.021$), although its contribution was lower than in the sprint group. BMI had an inverse relationship with performance ($\beta = -0.26$; $p = 0.048$), stressing the importance of mass-height balance in 800 and 1,500 m running. Thus, for middle distances, performance was determined not by a single anthropometric parameter but by the relationship between the muscle component, body mass, and fat mass.

In the long-distance group, the model explained 49% of the variability in mean running speed. The leading predictor was fat mass percentage ($\beta = -0.44$; $p = 0.003$), which pointed to its inverse relationship with performance during prolonged cyclic load. BMI also had a statistically significant inverse relationship ($\beta = -0.33$; $p = 0.014$), while body mass retained an independent contribution to the model ($\beta = -0.28$; $p = 0.039$). This model structure demonstrated that, over long distances, a more successful profile was associated with lower mass-height indicators and a smaller fat component. Unlike in sprinting, single-leg thigh circumference and muscle mass percentage were not among the significant predictors, reflecting a different morphological basis for long-distance performance.

The regression analysis showed that anthropometric predictors of performance differed according to distance specialisation. In sprinting, mean speed was determined mainly by the muscle component, single-leg thigh circumference, and lower-limb length. In middle-distance running, muscle mass percentage, fat mass percentage, and BMI were all relevant, reflecting the mixed speed-endurance character of the load. In long-distance running, performance was associated primarily with lower fat mass percentage, BMI, and body mass. In general, the regression models confirmed that anthropometric characteristics have different predictive roles in sprint, middle-distance, and long-distance running.

Practical recommendations for distance orientation in track-and-field athletes

The results provide grounds for practical recommendations on the use of anthropometric assessment in sports selection, refinement of distance specialisation, and individualisation of the training process. This does not mean setting rigid standards for body mass, BMI, thigh circumference, or the proportions of muscle and fat mass. Rather, these characteristics should be used as auxiliary reference points. The anthropometric profile should be interpreted together with control running results, running technique, functional readiness, training experience, and the athlete's response to load. This approach is important because the identified relationships pointed to not a universal advantage of a single body-build indicator but its different value according to distance specialisation. The results established that sprinters, middle-distance runners, and long-distance runners had different leading anthropometric predictors of performance, so coaching decisions should be differentiated rather than applied uniformly to all runners.

For athletes who show a pronounced muscle-strength profile and high speed capacity, orientation towards sprint events is appropriate. In this group, practical significance belongs not to total body mass in itself but to its functional structure, namely the predominance of active muscle component over inactive mass. If an athlete has sufficient development of lower-limb muscles, a higher muscle mass percentage, pronounced thigh circumference, and the ability to realise start acceleration quickly, this may point to favourable prerequisites for short distances. In the training process for such athletes, emphasis should be placed on the development of explosive strength, maximal push-off power, reactive muscle capacity, running-stride frequency, and start technique. The coach should also ensure that the body-mass increase does not occur through the fat component or through excessive muscle volume that does not improve speed realisation. In practical terms, this means regular monitoring of body composition, assessment of control-section dynamics, and comparison of strength indicators with actual running speed. If an increase in muscle mass is not accompanied by improvement in acceleration, stride frequency, or mean speed, strength training should be adjusted towards greater specialisation and speed orientation.

For middle-distance runners, recommendations should focus on maintaining a functional balance between muscular power, endurance, and movement economy. This specialisation requires neither the maximal muscle-strength profile typical of sprinting nor an excessively light body-build profile characteristic of long-distance runners. An athlete oriented towards 800 and 1,500 m should combine the ability to run at high intensity with the capacity to maintain pace as fatigue increases. In sports selection and subsequent preparation, it is necessary to assess the relationship between body mass, muscle component, fat mass, and BMI, instead of a single anthropometric indicator. If an athlete has an intermediate anthropometric profile, demonstrates sufficient speed over shorter sections, and can maintain a stable pace over longer control distances, they may be treated as a potential middle-distance runner. The training process for this group should combine speed-strength work, interval loads, tempo running, strength-endurance exercises, and recovery control. Excessive body-mass increase may complicate pace maintenance, whereas insufficient development of the muscle component may reduce the capacity for finishing acceleration and high-intensity work. Therefore, preparation should be adjusted not towards changing one indicator but towards preserving the optimal relationship between strength and endurance prerequisites for performance.

For long-distance runners, practical recommendations should be based on monitoring the mass-height profile, fat mass percentage, and the athlete's ability to maintain economical movement during prolonged load. The results showed that lower body mass, lower BMI, and a smaller fat component are more important for long-distance runners, but these indicators must not be interpreted as grounds for mechanical weight reduction. In training practice, long-term body-mass reduction without regard to functional state may impair recovery, reduce strength endurance, and increase the risk of overfatigue. The coach should assess body mass and body composition together with pace stability, tolerance of training volume, dynamics of results, and signs of recovery. If an athlete has a lighter body-build profile, lower fat mass percentage, stable running technique, and the ability to maintain an even pace for a long time, this may support orientation towards 5,000 and 10,000 m distances. Training for such track-and-field athletes should emphasise aerobic endurance, running economy, pace stability, and the ability to preserve effective technique under fatigue. Control of anthropometric indicators should serve a preventive function: it should identify excessive growth of inactive mass or, conversely, undesirable reduction of the muscle component in time.

In sports selection practice, the results may be used as an instrument for preliminary distance orientation. If the morphological profile of an athlete corresponds to

sprint prerequisites but control results do not show sufficient speed realisation, it is preferable not to change specialisation immediately, but first to analyse start technique, push-off force, stride frequency, and the quality of speed-strength preparation. If an athlete has an intermediate profile and unstable results between shorter and longer distances, testing under different pace regimes is appropriate to clarify whether the athlete performs better through speed, endurance, or their combination. If a track-and-field athlete has long-distance anthropometric prerequisites but does not show pace stability, functional readiness, aerobic training volume, and recovery capacity should be checked. The practical value of the data lies in the possibility of using the anthropometric profile as an additional basis for individualising preparation. Anthropometric indicators do not replace coaching observation, control starts, or functional testing, but they help explain more precisely why one athlete performs better in sprinting, another – in middle-distance running, and a third – in prolonged running. The most effective approach is comprehensive: body build, body composition, speed indicators, endurance, and technique should be viewed as interrelated components of sports performance.

Discussion

Comparison of the groups showed that the morphological characteristics of track-and-field athletes differed in their expression among sprinters, middle-distance runners, and long-distance runners. Sprinters had higher mass-height indicators, greater single-leg thigh circumference, and a higher muscle mass percentage, whereas long-distance runners had lower values for body mass, BMI, and fat component. Middle-distance runners occupied an intermediate position for most parameters. Correlation and regression analyses showed that the relationship between anthropometric characteristics and mean running speed was distance-specific: the muscle component and lower-limb parameters were more important for sprinting, whereas lower body mass and a smaller fat mass percentage were more important for long distances.

The results confirmed that the anthropometric profile of track-and-field athletes differed according to distance specialisation: among sprinters, body mass was 82.4 ± 6.8 kg, single-leg thigh circumference – 62.8 ± 3.4 cm, and muscle mass percentage – 47.8 ± 3.0%; in middle-distance runners, the corresponding values were 75.6 ± 6.1 kg, 59.6 ± 3.1 cm, and 45.9 ± 2.8%; and in long-distance runners – 70.8 ± 5.7 kg, 56.4 ± 2.9 cm, and 44.2 ± 2.6%. This gradation of indicators reflected a more pronounced muscle-strength component in sprinters, an intermediate anthropometric profile in middle-distance runners, and a lighter body-build profile in long-distance runners. This pattern is consistent with the data of C. Sanchez Munoz *et al.* (2020), who addressed anthropometric characteristics, body composition, and somatotype in young elite runners. The researchers showed that the morphological profile of runners is associated with specialisation, which coincides with the inter-group differences recorded in the present study. Similar results were obtained by C.A. Herrera-Amante *et al.* (2025), who analysed anthropometric characteristics and athletic performance in track-and-field athletes at different competition levels. Unlike the broader disciplinary approach in that work, the presented study specified the morphological factors of performance for sprint, middle-distance, and long-distance running. Partial correspondence with the results of M. Thuany *et al.* (2023a) is observed in the relationship between mass-height parameters and running performance. However, that paper treated BMI together with training volume as a mediator of performance, whereas the present study focused primarily on anthropometric differences between distance groups.

Mean running speed was 8.63 ± 0.41 m/s in sprinters, 5.71 ± 0.32 m/s in middle-distance runners, and 4.62 ± 0.28 m/s in long-distance runners; inter-group differences were statistically significant ($p < 0.001$). The standardised performance index also differed among the groups and was 0.71 ± 0.12 in sprinting, 0.64 ± 0.11 in middle-distance running, and 0.58 ± 0.10 in long-distance running. The difference between the speed profiles of sprinters and middle-distance runners corresponds to the results of O. Wiriawan & M. Kesa (2020), who compared the physical capacities of representatives of these specialisations. Their study underscored that sprint performance is associated with short-term speed realisation, whereas middle-distance events require a combination of speed, endurance, and the ability to maintain load intensity. The event-specific character of the results was also confirmed by M. George (2025), who analysed kinanthropometric predictors of performance in different athletics events. In contrast to the disciplinary approach of that researcher, the present study specified morphological performance factors for sprint, middle-distance, and long-distance running. The explanation of lower mean speed among long-distance runners is in agreement with the provisions of P.R. Hayes & D.A. Gordon (2021), who described the physiological determinants of middle and long distances. In this context, the speed of long-distance runners cannot be interpreted as a lower level of preparedness, because prolonged load is based on a different relationship between aerobic productivity, pace stability, and movement economy. Results concerning middle-distance runners were supplemented by the data of N.P. Radhakrishnan *et al.* (2025), who analysed the influence of training load, physiological features, and recovery on performance. This broadened the interpretation of the data obtained, as the mean speed in 800 and 1,500 m running is formed not only by anthropometric profile but also by functional readiness and the ability to maintain the required pace.

Correlation analysis showed that, in sprinting, mean speed was most closely associated with muscle mass percentage ($r = 0.62$), single-leg thigh circumference ($r = 0.58$), and lower-limb length ($r = 0.46$). In long-distance runners, the strongest inverse relationships were recorded for fat mass percentage ($r = -0.56$), BMI ($r = -0.52$), and body mass ($r = -0.48$). The relationship between body composition and 100 m performance described by A. Azim *et al.* (2025) aligns with the results of the present study for sprinters. In the sprint group, mean speed correlated most closely with muscle mass percentage and single-leg thigh circumference, confirming the role of the active muscle component in speed-strength realisation over a short distance. Y. Aikawa *et al.* (2020) addressed the relationship of height, body mass, muscle mass, fat mass, and fat percentage with sports results in male track-and-field athletes. Their data coincide

with the present results regarding the different directions of association between muscle and fat components and performance across running specialisations. The findings of J. Rosado *et al.* (2020) on body composition in long-distance runners correspond to the indicators obtained for long-distance runners in this study, where fat mass percentage and BMI had inverse correlations with mean speed. This comparison confirmed that, in prolonged running, performance is associated not only with endurance but also with a body-build profile that reduces the energetic cost of movement. D. Tomita *et al.* (2020) confirmed the relationship identified in the sprint group between lower-limb parameters and running speed. Direct comparison is limited, however, because those researchers analysed the length of separate bone segments of the lower limb, whereas the present study used the total anthropometric indicator of lower-limb length. J.F. Rickta *et al.* (2025) addressed the correlation between fat mass percentage and aerobic capacity in athletes and linked body composition with functional capacity. These data provide a broader explanation of the results obtained in the long-distance group, particularly the inverse relationship between fat mass percentage and mean running speed.

Regression analysis showed that, in sprinting, the model explained 51% of the variability in mean speed, and the significant predictors were muscle mass percentage ($\beta = 0.42$), single-leg thigh circumference ($\beta = 0.34$), and lower-limb length ($\beta = 0.27$). In middle-distance running, the model explained 46% of variability, in long-distance running – 49%. In both groups, fat mass percentage played a significant role with negative β coefficients. The analysis of runners' body composition by A. Dammicco & G. Reina (2025) supports the use of fat and muscle mass as variables in regression models of performance. In the present study, this is important for interpreting the models in which fat mass percentage had a negative β coefficient in the middle- and long-distance groups, while muscle mass percentage had a positive β coefficient in sprint and middle-distance running. M. Thuany *et al.* (2023b) interpreted the performance of runners over distances from 5 km to the marathon as the result of interaction among morphological, training-related, and social factors. This approach emphasised the multicomponent nature of sports achievement in endurance running. It corresponds to the long-distance regression model, in which fat mass percentage, BMI, and LLL/H explained variability in mean speed, although the current study focused specifically on anthropometric parameters. M.I. Black *et al.* (2020) addressed anthropometric factors in running economy, linking morphological characteristics with movement efficiency during running. Their conclusions deepen the explanation of the long-distance model, where lower fat mass percentage and lower BMI were associated with higher mean speed, since a reduction in inactive mass may lower the energetic cost of prolonged movement. H. Ueno *et al.* (2021) considered the role of body-segment mass in the performance of trained endurance runners. This partly corresponds to the regression model for long-distance runners, confirming the importance not only of total body mass but also of the distribution of mass across separate segments, which may affect running mechanics and energy expenditure. O. Kettunen *et al.* (2025) treated body composition as one factor that may explain differences in performance among elite endurance-profile athletes. This agrees with the long-distance model obtained during the study, in which fat mass percentage had the most pronounced inverse relationship with mean speed. Body composition functioned not as an auxiliary characteristic but as a statistically significant component of performance in endurance running.

The discussion confirmed that the results generally correspond to other studies in which anthropometric profile, body composition, and mass-height parameters are treated as factors associated with running performance. The strongest correspondence was observed in the confirmation of the muscle-strength profile of sprinters, the intermediate character of indicators in middle-distance runners, and the lighter body-build profile of long-distance runners. Nonetheless, a comparison with previous research showed that the importance of individual anthropometric characteristics changes according to distance specialisation and the structure of competitive load.

Conclusions

The results of the study displayed that the anthropometric profile of track-and-field athletes depends strongly on distance specialisation. Sprinters had the most pronounced mass-height and muscle indicators: body mass was 82.4 ± 6.8 kg, BMI – 25.1 ± 1.6 kg/m^2, single-leg thigh circumference – 62.8 ± 3.4 cm, mass percentage – 47.8 ± 3.0%. In middle-distance runners, these indicators had intermediate values: body mass was 75.6 ± 6.1 kg, BMI – 23.5 ± 1.4 kg/m^2, single-leg thigh circumference – 59.6 ± 3.1 cm, muscle mass percentage – 45.9 ± 2.8%. Long-distance runners had a lighter body-build profile, lower body mass of 70.8 ± 5.7 kg, lower BMI of 22.6 ± 1.3 kg/m^2, and a smaller fat mass percentage of 9.8 ± 1.8%, which was due to the requirements of prolonged cyclic load. Sports performance also differed among the groups. The highest mean speed was recorded in sprinters, at 8.63 ± 0.41 m/s; it was lower in middle-distance runners, at 5.71 ± 0.32 m/s, and lowest in long-distance runners, at 4.62 ± 0.28 m/s. Inter-group differences were statistically significant ($p < 0.001$). The standardised performance index was 0.71 ± 0.12 in sprinters, 0.64 ± 0.11 in middle-distance runners, and 0.58 ± 0.10 in long-distance runners ($p = 0.004$), confirming the relevance of assessing performance with reference to distance specificity rather than only absolute time to cover the distance.

Correlation analysis established that, in sprinters, mean speed was most closely associated with muscle mass percentage ($r = 0.62$), single-leg thigh circumference ($r = 0.58$), and lower-limb length ($r = 0.46$). In middle-distance runners, performance was associated with muscle mass percentage ($r = 0.45$), fat mass percentage ($r = -0.49$), and BMI ($r = -0.41$), reflecting the mixed character of this specialisation. In long-distance runners, the closest inverse relationships were recorded for fat mass percentage ($r = -0.56$), BMI ($r = -0.52$), and body mass ($r = -0.48$), emphasising the importance of a lighter mass-height profile for endurance work. The regression models confirmed the specialised role of anthropometric characteristics in performance. In sprinting, 51% of the variability in mean speed was explained by muscle mass percentage, single-leg thigh circumference, and lower-limb length. In middle-distance

running, the model explained 46% of performance variability through fat mass percentage, muscle mass percentage, and BMI. In the long-distance group, 49% of the variability in mean speed was explained by fat mass percentage, BMI, and body mass. Thus, anthropometric characteristics do not have a universal influence on performance: muscle-strength parameters are leading in sprinting, the balance between muscle and fat components is important for middle distances, and lower fat mass percentage and a more economical body-build profile are more important for long distances. Further research should use a longitudinal design with repeated measurements at different stages of the training cycle, which would allow the dynamics of anthropometric characteristics and sports performance to be traced during preparation. The generalisability of the results should be improved by expanding the sample by sex, age, and level of sports qualification, including female athletes, juniors, adult track-and-field athletes, and representatives of different qualification groups.

Acknowledgements

None.

Funding

None.

Conflict of Interest

None.

References

[1] Aikawa, Y., Murata, M., & Omi, N. (2020). Relationship of height, body mass, muscle mass, fat mass, and the percentage of fat with athletic performance in male Japanese college sprinters, distance athletes, jumpers, throwers, and decathletes. *The Journal of Physical Fitness and Sports Medicine*, 9(1), 7-14. doi: 10.7600/jpfsm.9.7.

[2] Azim, A., Hossain, J., Ceylan, H.I., Muntean, R.I., & Haque, M.M. (2025). Unlocking the fast track: Exploring the interplay between body composition and athletes' performance in the 100 m sprint. *Motricidade*, 21, article number e40642. doi: 10.6063/motricidade.40642.

[3] Black, M.I., Allen, S.J., Forrester, S.E., & Folland, J.P. (2020). The anthropometry of economical running. *Medicine & Science in Sports & Exercise*, 52(3), 762-770. doi: 10.1249/MSS.0000000000002158.

[4] Christou, G.A., Pagourelias, E.D., Deligiannis, A.P., & Kouidi, E.J. (2021). Exploring the anthropometric, cardiorespiratory, and haematological determinants of marathon performance. *Frontiers in Physiology*, 12, article number 693733. doi: 10.3389/fphys.2021.693733.

[5] Dammicco, A., & Reina, G. (2025). Body composition analysis in runners using bioimpedance technique. *IEEE Access*, 13, 208212-208226. doi: 10.1109/ACCESS.2025.3635046.

[6] George, M. (2025). Kinanthropometric predictors of event-specific performance in track and field athletes. *Sports Science & Health Advances*, 3(1), 394-402. doi: 10.60081/SSHA.3.1.2025.394-402.

[7] Hayes, P.R., & Gordon, D.A. (2021). Physiological determinants of middle-and long-distance running. In R. Blagrove & P. Hayes (Eds.), *The science and practice of middle and long distance running* (pp. 3-16). New York: Routledge. doi: 10.4324/9781003088912-2.

[8] Herrera-Amante, C.A., Carvajal-Veitía, W., Octavio Ramos-García, C., Garcia-Carrillo, E., Cortés-Roco, G., Olivares-Arancibia, J., Aguilera-Martínez, N., & Yáñez-Sepúlveda, R. (2025). Anthropometric characteristics, somatotype, and body composition: Differences by sport category and sex in elite Cuban and Mexican track and field athletes. *International Journal of Morphology*, 43(2). doi: 10.4067/S0717-95022025000200527.

[9] Ivanyshyn, I., Vypasniak, I., Ivanyshyn, Y., Boichuk, R., Vintoniak, O., & Tretiak, D. (2024). Spirographic study of functional reserves of masters' athletes in track-and field. *Pedagogy of Physical Culture and Sports*, 28(6), 468-478. doi: 10.15561/26649837.2024.0601.

[10] Kettunen, O., Mikkola, J., & Ihalainen, J.K. (2025). Associations between body composition and performance in elite endurance athletes. *International Journal of Sports Physiology and Performance*, 20(11), 1530-1537. doi: 10.1123/ijspp.2024-0506.

[11] Kolot, A., Sovenko, S., & Rezanov, O. (2025). Theoretical and methodological foundations for improving technical skills of highly skilled athletes in track and field competitions. *Journal of Physical Education and Sport*, 25(7), 1353-1364. doi: 10.7752/jpes.2025.07151.

[12] Nikolaidis, P.T., & Knechtle, B. (2024). Physiology of marathon: A narrative review of runners' profile and predictors of performance. *Physiologia*, 4(3), 317-326. doi: 10.3390/physiologia4030019.

[13] Novikova, I., Prus, N., & Uskova, S. (2025). Specific aspects of the impact of track and field training on human health. *Scientific Journal of the Ukrainian State University Named After Mykhailo Drahomanov. Series 15*, 5(192), 109-112. doi: 10.31392/UDU-nc.series15.2025.05(192).24.

[14] Pavlovic, R., Mihajlović, I., Radulović, N., & Nikolić, S. (2022). Anthropometric parameters of elite male runners sprint: Are body height and body weight predictors of results. *Health, Sport, Rehabilitation*, 8(3), 64-74. doi: 10.34142/HSR.2022.08.03.05.

[15] Peyré-Tartaruga, L.A., Machado, E., Guimarães, P., Borba, E., Tartaruga, M.P., Buzzachera, C.F., Correale, L., Lanferdini, F.J., & da Silva, E.S. (2024). Biomechanical, physiological and anthropometrical predictors of performance in recreational runners. *PeerJ*, 12, article number e16940. doi: 10.7717/peerj.16940.

[16] Polianska, O.S., Hrechko, S.I., Tovkach, Yu.V., Tashchuk, L.V., Skoreiko, P.M., & Andriiets, M.M. (2025). The significance of anthropometric assessment results for predicting athletic performance. *Current Problems of Modern Medicine: Bulletin of the Ukrainian Medical Stomatological Academy*, 25(1), 70-74. doi: 10.31718/2077-1096.25.1.70.

[17] Radhakrishnan, N.P., *et al.* (2025). Analysis of performance determinants in middle-distance runners: The influence of training load, physiological traits, and recovery indicators. *International Journal of Human Movement and Sports Sciences*, 13(5), 1003-1015. doi: 10.13189/saj.2025.130501.
[18] Rickta, J.F., Arafat, Y., Mukta, F.T.J., & Islam, R. (2025). Correlation between body fat percentage and aerobic capacity in various athletes: An open assessment. *Scientific Journal of Sport and Performance*, 4(1), 85-91. doi: 10.55860/XEOZ6800.
[19] Rosado, J., *et al.* (2020). Body composition among long distance runners. *Revista da Associação Médica Brasileira*, 66, 180-186. doi: 10.1590/1806-9282.66.2.180.
[20] Sanchez Munoz, C., Muros, J.J., Lopez Belmonte, O., & Zabala, M. (2020). Anthropometric characteristics, body composition and somatotype of elite male young runners. *International Journal of Environmental Research and Public Health*, 17(2), article number 674. doi: 10.3390/ijerph1702067.
[21] Stachoń, A., Pietraszewska, J., & Burdukiewicz, A. (2023). Anthropometric profiles and body composition of male runners at different distances. *Scientific Reports*, 13, article number 18222. doi: 10.1038/s41598-023-45064-9.
[22] The Declaration of Helsinki. (2024). Retrieved from https://www.wma.net/wp-content/uploads/2024/10/DoH-Oct2013.pdf.
[23] Thuany, M., Hill, L., Alvero-Cruz, J.R., Knechtle, B., & Gomes, T.N. (2023a). The relationship between training volume and bmi in the expression of running performance in runners: A mediation model. *Journal of Science in Sport and Exercise*, 5(2), 142-148. doi: 10.1007/s42978-022-00172-2.
[24] Thuany, M., Knechtle, B., Santana, A., & Gomes, T.N. (2023b). Anthropometric, training, and social variables associated with performance in runners from 5 km to marathon. *Science & Sports*, 38(3), 310.e1-310.e8. doi: 10.1016/j.scispo.2022.04.005.
[25] Tomita, D., Suga, T., Terada, M., Tanaka, T., Miyake, Y., Ueno, H., Otsuka, M., Nagano, A., & Isaka, T. (2020). A pilot study on a potential relationship between leg bone length and sprint performance in sprinters; Are there any event-related differences in 100-m and 400-m sprints? *BMC Research Notes*, 13(1), article number 297. doi: 10.1186/s13104-020-05140-z.
[26] Ueno, H., Suga, T., Takao, K., Terada, M., Nagano, A., & Isaka, T. (2021). Relationship between body segment mass and running performance in well-trained endurance runners. *Journal of Applied Biomechanics*, 37(6), 531-537. doi: 10.1123/jab.2020-0239.
[27] Vdovenko, N.V., Husarova, A.M., Maidaniuk, O.V., Osypenko, H.A., & Kozak, I.O. (2024). Fat content in qualified athletes of different specialties. *Olympicus*, 2, 45-50. doi: 10.24195/olympicus/2024-2.6.
[28] Wiriawan, O., & Kesa, M. (2020). Physical analysis of capacity of sprint and middle distance runners. *International Journal of Innovation Creation Change*, 14(4), 557-567.

Вплив антропометричних даних на результативність легкоатлетів у бігових дисциплінах

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Анотація. Мета дослідження полягала у з'ясуванні особливостей зв'язку антропометричних характеристик легкоатлетів із результативністю у спринті, бігу на середні й довгі дистанції. Дослідження проводилося 6-10 квітня 2025 року на базі Університету Григорія Сковороди в Переяславі, за участю 90 легкоатлетів чоловічої статі віком 18-24 роки, розподілених на групи спринту, бігу на середні та довгі дистанції, з оцінюванням антропометричних показників, контрольних бігових результатів і статистичних зв'язків між фізичними параметрами та спортивною результативністю. Отримані результати засвідчили, що антропометричний профіль, швидкість бігу, кореляційні зв'язки та регресійні предиктори мали дистанційну специфіку. Спринтери характеризувалися вищою масою тіла, окружністю стегна однієї ноги та часткою м'язової маси – 82,4 ± 6,8 кг, 62,8 ± 3,4 см і 47,8 ± 3,0 %, що відображало перевагу м'язово-силового компонента на коротких дистанціях. У стаєрів нижчі маса тіла, індекс маси тіла і жирова маса – 70,8 ± 5,7 кг, 22,6 ± 1,3 кг/м² і 9,8 ± 1,8 % – були пов'язані з економізацією тривалого бігу. Середня швидкість становила 8,63 ± 0,41, 5,71 ± 0,32 і 4,62 ± 0,28 м/с відповідно у групах спринту, середніх і довгих дистанцій. Кореляції показали зв'язок швидкості у спринті з м'язовою масою (r = 0,62), а у стаєрів – обернений зв'язок із жировою масою (r = -0,56). Регресійні моделі пояснили 51 %, 46 % і 49 % варіативності швидкості, підтверджуючи різну роль антропометричних чинників у кожній біговій спеціалізації. Результати підтвердили, що антропометричні чинники результативності відрізняються за біговою спеціалізацією: у спринті переважають м'язово-силові параметри, у довгих дистанціях – нижча жирова маса та економічніший тілобудовний профіль. Практично ці дані можуть використовувати тренери, викладачі легкої атлетики та фахівці зі спортивного відбору для уточнення дистанційної спеціалізації й індивідуалізації тренувального процесу

Ключові слова: дистанційна спеціалізація; спринт; індекс маси тіла; тілобудова; стаєри; швидкісно-силова реалізація; витривалість

Scientific and practical journal
“THEORY AND PRACTICE
OF PHYSICAL CULTURE AND SPORTS”

Volume 5, No. 1
2026

Managing Editor:
A. Pyvovar

Signed to the print with the original layout 12.05.2026
Conventional Printed Sheet 12.8
Circulation 100 copies

Publisher:
Hryhorii Skovoroda University in Pereiaslav
08401, 30 Sukhomlynskoho Str., Pereiaslav, Ukraine
E-mail: mail@tppcs.com.ua
https://tppcs.com.ua/

Науково-практичний журнал
«ТЕОРІЯ І ПРАКТИКА
ФІЗИЧНОЇ КУЛЬТУРИ І СПОРТУ»

Том 5, № 1
2027

Відповідальний редактор:
А. Пивовар

Підписано до друку з оригінал-макета 12.05.2026
Ум. друк. арк. 12,8
Тираж 100 примірників

Видавництво:
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