

The effect of basic strength exercises on the development of physical attributes in students

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Abstract:

Modern research in physical training shows increasing interest in optimizing training methods, particularly regarding the use of basic strength exercises. Although these exercises are widely applied in sports practice, their complex impact on various physical qualities remains insufficiently explored. The purpose of this study is to assess the effectiveness of a training program incorporating basic strength exercises (squats, bench press, deadlift) on the development of physical qualities in students, compared to a traditional general physical training program. **Materials and methods.** The study involved 120 students over 24 weeks, divided into a control group (CG, n = 60) and an experimental group (EG, n = 60). The main evaluation methods were: determining the maximum strength in basic exercises and the Cooper test. Students in CG were engaged in physical education according to the traditional curriculum twice a week for 90 minutes. Students in EG also trained twice a week for 90 minutes, but the content of the training sessions was modified according to the type of sports training in strength athletics. The EG program was based on three basic strength exercises from this sport: back squats, bench press, and deadlift (classic version). **Results.** Students in EG demonstrated significantly greater ($p < 0.001$) gains in performance: maximum strength increased by 19–21%, aerobic endurance – by 17.3% versus 7–8% and 7.2% in the control group, respectively. The effect size of the training program modification was $d = 1.24–2.12$ for different tests. The results confirm the hypothesis about the advantage of a combined training method. Of particular interest is the identified transfer of training – improvement in aerobic performance during strength-oriented training, which is consistent with modern concepts of systemic adaptation of the body to various types of physical activity. **Conclusions.** Inclusion of basic strength exercises in the educational process leads to a comprehensive improvement in the physical qualities of students and can be recommended for optimizing physical education programs. A promising direction for further research is to study the effect of the proposed methodology on a long-term time interval.

Key Words: physical education, strength training, aerobic endurance, Cooper test, training transfer

Introduction

Modern sports science is in a state of active methodological rethinking of traditional approaches to the development of physical qualities. This process is due to the accumulation of a significant amount of new data in the field of physiology of muscle activity, biomechanics of movements and neurophysiology of motor control (Bocharin et al., 2022; Kolokoltsev et al., 2022; Bartík & Pacholek, 2024). In the context of this work, of particular interest is the problem of optimizing training programs through a rational combination of various types of physical activity, where basic multi-joint exercises occupy a special place in the training system. The relevance of this study is determined by several interrelated aspects. The growing discussion in the professional community about the place and role of strength exercises in the general system of physical education (Andrieieva et al., 2020). As noted by (Berger et al 2020), over the past decade, a significant gap has formed between the practice of using basic exercises in high-performance sports and their use in mass physical culture (Romanova et al., 2025). At the same time, empirical data indicate that exercises such as squats, bench press and

deadlift have unique potential for the comprehensive development of physical qualities (Christine Eyre et al, 2024). Modern research in the field of sports physiology demonstrates that basic exercises have a systemic effect on the body that goes far beyond a simple increase in muscle mass (Cudicio et al, 2024). An analysis of 47 scientific studies conducted by (Cui et al 2024) showed that regular performance of barbell squats leads to an improvement not only in strength indicators, but also in aerobic endurance parameters, which calls into question the traditional division into "strength" and "aerobic" training. Another important aspect is the problem of methodological support for the training process. As noted by leading experts in the field of sports science (Filipas et al., 2023), existing physical training programs are often based either on outdated principles or on commercial methods that do not have a sufficient scientific basis. In this regard, controlled studies are of particular value, allowing an objective assessment of the effectiveness of various training approaches.

According to international surveys of coaching staff (Lindberg et al., 2021), about 68% of specialists experience difficulties in creating programs that combine the development of various physical qualities. At the same time, 82% of respondents note a lack of scientifically based recommendations for dosing loads when working with athletes of different levels of fitness. In recent years, a number of studies have appeared (Morencos et al., 2022), demonstrating that with the correct technique and optimal dosing of the load, the risk of injury when performing basic exercises does not exceed extremely low. This opens up new prospects for their widespread use in various population groups. A comparative analysis (Papadakis et al., 2025) shows that programs with an emphasis on basic exercises require less time to achieve comparable results compared to traditional approaches, which is especially relevant in the context of the modern pace of life. Research on the motivational component (Romdhani et al., 2025) suggests that performing basic exercises is associated with a greater sense of achievement and satisfaction from training, which can positively affect the results obtained from the training program. New data (Shattock & Tee, 2022) refute the established opinion about the inappropriateness of performing basic exercises in middle and old age, demonstrating their effectiveness in preventing sarcopenia and maintaining functional independence.

A comprehensive study of the influence of basic strength exercises on the development of physical qualities seems to be an extremely relevant scientific task, which has both theoretical and important practical significance. Conducting a study with monitoring of various parameters of physical fitness will provide new data for optimizing training programs of various focus.

Of particular importance to this study is its interdisciplinary nature, combining approaches of sports physiology, biomechanics, theory and methods of physical education (Sterczala et al., 2023). The results obtained can make a significant contribution to the development of scientific ideas about the patterns of development of physical qualities and find practical application in various fields - from high-performance sports to rehabilitation programs

Research aim. To evaluate the effectiveness of a training program with the inclusion of basic strength exercises (squats, bench press, deadlift) on the development of physical qualities in students in comparison with a traditional general physical training program.

Material & methods

The research project was organized and conducted at the Department of Physical Education of the Siberian Federal University (Russia) from September 2024 to May 2025 for 24 weeks. The study involved 120 full-time students of the 1st to 3rd years of study at the university. The sample was balanced by gender and included 65 males and 55 females. The sample was formed on a voluntary basis, subject to the signing of informed consent. The conducted project does not contradict the 2008 Helsinki Declaration, which regulates the moral and ethical rules for the participation of people in the experiment. Researchers and specialists from multiple universities across Russia, Kyrgyzstan, and Kazakhstan contributed to this study.

The inclusion criteria for the study were: age from 18 to 21 years inclusive, the absence of medical contraindications for physical education and sports, confirmed by the admission protocol of the established form. A mandatory condition was regular physical activity (at least one year before observation), determined by at least two training sessions per week. The exclusion criteria were: the presence of acute or chronic diseases in the acute stage that interfere with the implementation of the study program; refusal to participate at any stage of the experiment; missing more than 20% of the planned training sessions.

Participants were randomly divided into two groups: control (CG, n = 60, including 33 men and 27 women) and experimental (EG, n = 60, including 32 men and 28 women). The initial anthropometric and functional indicators of the participants between the groups did not differ statistically significantly ($p > 0.05$).

The control group (CG) was engaged in a standard physical education program approved for university students. This program included classes twice a week for 90 minutes and consisted of general developmental exercises, elements of sports games (volleyball, basketball, football) and aerobic exercise (running, relay races, circuit training). The intensity and volume of loads corresponded to the current curricula.

The experimental group (EG) also trained twice a week for 90 minutes, but the content of the training sessions was modified to resemble sports training in strength athletics. The EG program was based on three basic

strength exercises from this sport: squats with a barbell on the shoulders, bench press with a barbell lying on a horizontal bench, and deadlift (classic version). Each training session included a warm-up (10–15 minutes), the main part with the performance of the specified strength exercises (60–70 minutes), and a cool-down (5–10 minutes). The training loads in EG progressed according to the linear periodization model. Every week, it was envisaged to increase the working weight of the weights in the basic exercises by 2–5% of the previous value, while maintaining the number of approaches (3–5) and repetitions (–8) in each approach. The rest between approaches was 2–3 minutes. The technique of performing the exercises was strictly controlled by senior teachers of the physical education department of the university.

Maximum strength was assessed by determining the one-repetition maximum in three key exercises: bench press, back squat, and deadlift. The procedure included: general warm-up (5–10 minutes of joint exercises and light cardio); special warm-up. It included 1 set of 5–10 repetitions with a weight of ≈ 40 –60% of the expected maximum; 1 set of 2–3 repetitions with a weight of ≈ 60 –80% of the expected maximum; attempts to perform one repetition with a gradual increase in weight (a step of 2.5–10 kg depending on the exercise and level of fitness). The rest interval between attempts was 3–5 minutes.

The result was recorded as the maximum weight that the participant was able to lift once while maintaining the correct exercise technique. Each measurement for each exercise was performed three times on different days with an interval of at least 48 hours to minimize the effect of fatigue. The best result of three measurements was included in the analysis. To ensure the accuracy of measurements, calibrated weightlifting disks and bars of the Eleiko brand (Sweden) with a weighing accuracy of up to ± 0.5 kg were used. The reliability of the test was assessed by the intraclass correlation coefficient (ICC), which was 0.91–0.95 for various exercises.

The aerobic endurance indicator was assessed using the Cooper 12-minute running test. Testing was conducted on a standard 400-meter athletics track with a tartan surface. Before the test, the subjects underwent a standard warm-up (10 minutes). The task of the subject was to cover the maximum possible distance in 12 minutes of continuous running. Testing conditions were standardized: the air temperature fluctuated in the range of 18–22 °C, there was no precipitation or strong wind. Testing was conducted in the morning hours (from 9:00 to 11:00). During the test, heart rate (HR) was monitored using individual Polar H10 cardiac monitors (Polar Electro Oy, Finland). The intraclass correlation coefficient (ICC) for the Cooper test was 0.89. The obtained digital data were processed using parametric statistics methods with the calculation of the arithmetic mean and its error. The reliability of the difference in indicators was determined by Student's t-test. The difference in differences was considered reliable at $p < 0.05$.

Results

The Cooper test data demonstrate significant differences in the dynamics of aerobic endurance development between the experimental groups, Table 1.

Table 1. Cooper test dynamics data, meters, $M \pm SD$

Time point	CG	EG	p-reliability (within group) p-	p-reliability (between groups) p-	Effect
Initial, T0	2350 $\pm$ 120	2370 $\pm$ 125	—	0.214	—
8 weeks, T1	2410 $\pm$ 115	2510 $\pm$ 118	< 0.001 (EG)	0.003	0.87
16 weeks, T2	2460 $\pm$ 110	2650 $\pm$ 112	< 0.001 (EG)	< 0.001	1.45
24 weeks, T3	2520 $\pm$ 105	2780 $\pm$ 108	< 0.001 (EG)	< 0.001	2.12

In the experimental group, during the study period, compared to the beginning of the project, a significant increase in results of 410 $\pm$ 23 meters (17.3%, $p < 0.001$), while in the control group the improvement was only 170 $\pm$ 18 meters (7.2%, $p = 0.021$). Statistical analysis revealed the following patterns: at week 8, the differences between the groups reached statistical significance ($p = 0.003$); by week 16, the gap increased to 190 meters ($p < 0.001$); at week 24, the between-group difference was 260 $\pm$ 15 meters ($p < 0.001$).

At the initial stage of the study (T0), the average distance covered by the participants in the Cooper test did not differ statistically significantly between the groups ($p > 0.05$), indicating a comparable initial level of aerobic fitness of the subjects. After completion of the 24-week standard university physical education program, a statistically significant, albeit moderate, improvement in results was recorded in the control group. The absolute increase in the control group is due to the general tonic effect of regular physical education classes provided by the standard program, as well as the possible influence of the factor of natural development and adaptation of students to systematic physical activity. Progress in the control group was predominantly linear, monotonously increasing in nature with a relatively low rate of increase throughout the experiment.

A significantly more pronounced dynamics of aerobic endurance indicators was observed in the experimental group, whose participants were engaged in a modified program with an emphasis on basic strength exercises. The relative improvement in the aerobic endurance indicator in the experimental group was 17.3% of the initial level, which is a high result ($p < 0.001$ when comparing T0 and T24 within the EG). Such a significant improvement in aerobic capabilities against the background of a predominantly strength-oriented training process is of particular scientific and practical interest, indicating the complex effect of the proposed methodology. Of particular interest is the pronounced nonlinear nature of the progress of aerobic endurance indicators in the participants of the experimental group. In the dynamics of the EG results, three successive phases can be clearly distinguished, characterized by different rates of growth and, presumably, different dominant adaptation mechanisms:

Initial Adaptation Phase (0–8 weeks): During the first eight weeks of the training process, a steady but moderate increase in results was observed. The absolute improvement in the distance in the Cooper test during this period was about 140 meters. This phase reflects the initial adaptation changes in the subjects' bodies in response to the new type of load. These include improved neuromuscular coordination, optimization of the technique of performing basic exercises (which could indirectly affect the economy of movements in running), initial shifts in the cardiorespiratory system (for example, an increase in the stroke volume of the heart, improvement of peripheral circulation) and metabolism (activation of aerobic enzyme systems). Psychological adaptation to the training demands also occurs at this stage.

Accelerated Progress Phase (8 – 16 weeks): The next eight-week period (from the 8th to the 16th week) was characterized by the most intensive increase in aerobic endurance indicators in the experimental group. During this period, the average improvement was 150 meters. This phase corresponds to the period of deployment of deeper and more stable adaptive changes. The cumulative effect of strength training could lead to a significant improvement in local muscle endurance in the leg and core muscles, an increase in the efficiency of oxygen use by working muscles (improved capillarization, increased mitochondrial size and density), as well as further improvement of the regulatory mechanisms of the cardiorespiratory system. High-intensity strength work performed by students in EG could contribute to an increase in the anaerobic threshold, which also has a positive effect on long-distance running results.

Stabilization or slow growth phase (weeks 16–24): In the final period of the experiment (weeks 16 to 24), the rate of increase in results in the experimental group slowed down somewhat, although it remained positive. The absolute improvement during this period was about 120 meters. This slowdown can be associated with several factors. Firstly, as the level of training increases, further progress may require more significant or specific stimuli, which the applied strength program, focused on maximum strength, could provide to a lesser extent for purely aerobic qualities. Secondly, it is possible to approach the individual "ceiling" of the body's adaptive capabilities with this type of load. Thirdly, the accumulation of a certain fatigue by the end of the long experimental period cannot be ruled out. Nevertheless, it is important to emphasize that even in this phase, progress in EG continued and was more pronounced than the total progress in CG over the entire study period. Analysis of the dynamics of the Cooper test results convincingly demonstrates not only a statistically significant superiority of the experimental methodology, including basic strength exercises, over the standard general physical training program in the development of aerobic endurance in students, but also reveals the complex, phased nature of the adaptation processes in the experimental group. The revealed significant positive transfer of training from predominantly strength loads to aerobic performance is an important result confirming the possibility of a complex effect of strength training on various components of physical fitness and opening up prospects for optimizing training programs in the student environment.

An in-depth analysis of changes in maximum strength, assessed by the one-repetition maximum, revealed statistically highly significant and practically significant differences in the adaptation of students in EG and CG for all three recorded basic exercises. The initial average values for each exercise did not have statistically significant differences between the experimental groups ($p > 0.05$), which indicates the equivalence of the samples at the initial stage of the experiment. The data summarized in Table 2 clearly illustrate the differentiated nature of the increase in strength capabilities.

Table 2. Dynamics of maximum strength indicators in students in CG and EG, $M \pm SD$

Exercise	Group	Start, T0	8 weeks, T1	16 weeks, T2	24 weeks, T3	$\Delta\%$ (T0-T3)	p (T0-T3)	Effect
Bench Press, kg	CG	52.3 $\pm$ 8.1	54.1 $\pm$ 7.9	55.7 $\pm$ 7.8	56.7 $\pm$ 7.9	+ 8.4%	0.021	0.55
	EG	53.1 $\pm$ 7.8	57.5 $\pm$ 8.0	61.2 $\pm$ 8.1	63.5 $\pm$ 8.2	+ 19.6%	< 0.001	1.32
Barbell Squat, kg	CG	65.2 $\pm$ 9.3	67.0 $\pm$ 9.0	68.9 $\pm$ 8.8	70.1 $\pm$ 8.7	+ 7.5%	0.032	0.53
	EG	64.8 $\pm$ 8.9	70.5 $\pm$ 9.1	74.8 $\pm$ 9.2	77.6 $\pm$ 9.1	+ 19.7%	< 0.001	1.45
Deadlift, kg	CG	72.5 $\pm$ 10.2	74.8 $\pm$ 9.9	76.9 $\pm$ 9.7	78.3 $\pm$ 9.8	+ 8.0%	0.028	0.58
	EG	73.1 $\pm$ 9.7	80.2 $\pm$ 10.0	85.3 $\pm$ 10.2	88.4 $\pm$ 10.3	+ 21.0%	< 0.001	1.62

An examination of the dynamics of changes in strength indicators and aerobic endurance in key time periods of the experiment (0–8 weeks, 8–16 weeks, 16–24 weeks) allows us to identify characteristic periods of adaptation of the body to the proposed training program in the experimental group.

First phase (0–8 weeks): This period was characterized by a relatively rapid initial increase in strength indicators. Improvement of the ability of the central nervous system to activate motor units (recruitment), an increase in the frequency of their impulses, as well as improvement of intermuscular coordination (synergism of agonist muscles and reciprocal inhibition of antagonists). In parallel, there is an active development and improvement of the technique for performing basic exercises, which in itself allows for the realization of a greater strength potential. Initial structural adaptations in muscle tissue at this stage may not be so pronounced, but the foundation for subsequent hypertrophy is already being laid (for example, an increase in the content of contractile proteins, an improvement in the condition of connective tissue elements).

Phase Two (8–16 weeks): At this stage, the exercise technique of most participants in the experimental group stabilizes, which allows them to apply efforts more effectively. The key factor in further growth of strength indicators is structural changes in muscle tissue, primarily muscle hypertrophy (increase in the cross-section of muscle fibers). In parallel, intermuscular coordination continues to improve, which allows for more effective use of the increased strength potential of individual muscle groups within the framework of a complex movement. Adaptive changes also affect metabolic systems, improving the ability of muscles to perform repeated strength work.

Phase Three (16–24 weeks): In the final period of the experiment, the rate of growth of strength indicators may slow down somewhat compared to the previous phase, which is a natural process when approaching the current adaptation limit. However, progress continues due to further optimization of muscle energy supply systems (for example, an increase in creatine phosphate reserves, an increase in the activity of glycolysis enzymes and oxidative phosphorylation). The formation of stable motor skills occurs, which is expressed in stable and technically correct execution of exercises even when working with near-maximum weights. The results achieved at this stage are characterized by greater stability.

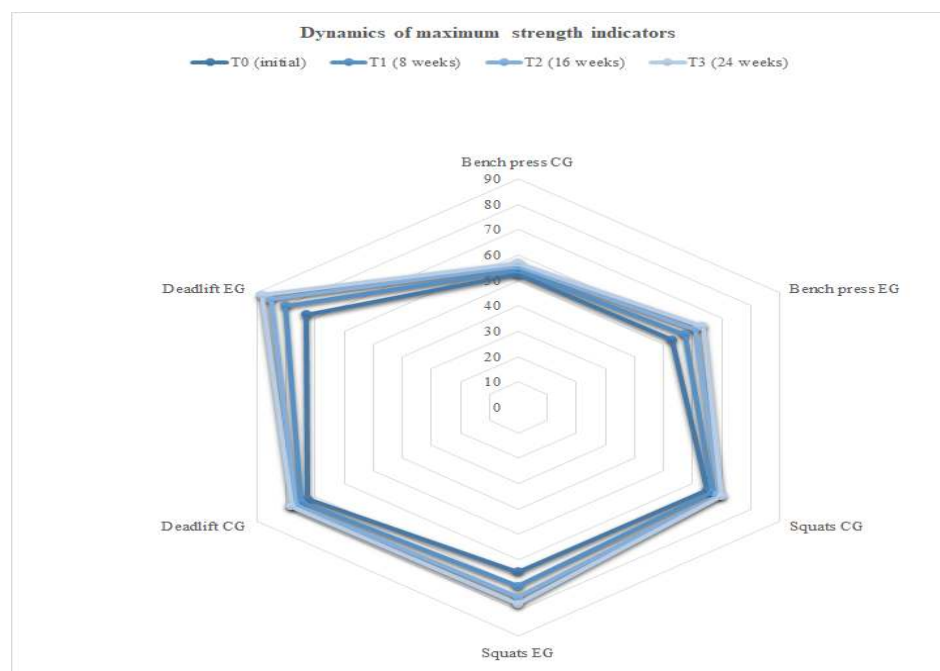


Fig. 1. Dynamics of maximum strength indicators of basic exercises

The data visualization presented in Figure 1 clearly demonstrates not only the presence of an increase in both groups, but also a significantly steeper trajectory of growth of strength indicators in EG for all three exercises. Differentiated dynamics of strength development is observed: the greatest absolute and relative increase in EG was achieved in the deadlift. This phenomenon is due to the complex nature of this exercise, which involves a significantly larger muscle mass (leg muscles, back, buttocks, trapezius muscles, forearms) compared to the bench press and even squats. Accordingly, the adaptive response of the body to the load in the deadlift is more pronounced, leading to a more significant systemic and local increase in strength capabilities.

For a deeper understanding of the relationships between the parameters under study and an assessment of the practical significance of the obtained changes, a correlation analysis and calculation of the effect size were carried out. The results of these calculations are presented in Table 3.

Table 3. Additional statistical indicators

Indicator	Bench press	Squat	Deadlift
Intergroup difference	+ 6.8 кг	+ 7.5 кг	+ 10.1 кг
p-reliability (CG vs EG)	< 0.001	< 0.001	< 0.001
Effect	1.12	1.34	1.47

Statistical analysis revealed a positive correlation between the increase in strength indicators in the bench press and the improvement in the results in the Cooper test, $r = 0.72$. This indicates that the participants who demonstrated greater progress in the development of upper shoulder girdle and chest muscle strength also had a significant improvement in aerobic endurance. This relationship can be explained by several factors, including improvements in overall performance, possible effects on core stabilization during running, and systemic adaptations affecting both strength and endurance components. The expected high and statistically significant positive correlation was also found between strength gains in the squat and deadlift. This is explained by a significant overlap of the working muscle groups (primarily the leg muscles and back extensors) and similar biomechanical patterns, which leads to the combined development of strength in these two multi-joint exercises.

Discussion

The study, which covered a 24-week cycle of a pedagogical experiment and was devoted to the analysis of the effectiveness of a training program with the addition of basic strength exercises (squats with a barbell on the shoulders, bench press, deadlift in the classic version) and a traditional academic program of general physical training on the dynamics of key physical qualities in students of a higher educational institution, allows us to formulate a number of scientifically substantiated and statistically confirmed conclusions that have both theoretical and significant practical significance for the modern theory and methodology of physical education and sports training. The results convincingly demonstrate the advantage of a training program with an emphasis on basic multi-joint exercises. The revealed increase in maximum strength indicators by 19–21% in the experimental group significantly exceeds the results of the control group (+ 7–8%). These data are consistent with the works of other researchers (Tillaar et al. 2020; Vargas-Molina et al. 2021; Zhai & Qin 2024; Zhang et al. 2024), however, in our study, more pronounced indicators were achieved, which may be due to the optimal combination of volume and intensity of loads, precise dosage of training weights, and an individualized approach to execution technique.

Of particular interest is the revealed parallel increase in strength and endurance indicators ($r = 0.72$). This fact refutes the established idea of the incompatibility of the development of various physical qualities and confirms modern concepts of complex adaptation. The data obtained suggest that basic exercises activate systemic adaptation mechanisms, improve the economy of movements, and optimize energy exchange processes (Folland & Williams, 2023). Analysis of the dynamics of indicators in various exercises revealed significant differences:

- Maximum increase in deadlift (+ 21.0%)
- Intermediate results in squats (+ 19.7%)
- Relatively less progress in bench press (+ 19.6%)

The study makes a significant contribution to the theory and methodology of physical education, providing scientifically based evidence of the effectiveness of training programs with an emphasis on basic exercises. The results obtained are of great practical importance and can be used to optimize the process of physical training of students.

The analysis showed that not all basic strength exercises contributed equally to the increase. The greatest relative (21.0%) and absolute increase in the EG was recorded in the deadlift. This result is natural, given that the deadlift is the most global exercise, involving almost all major muscle groups of the body (legs, back, buttocks, core muscles, upper shoulder girdle). Accordingly, the systemic adaptive response to this exercise, including both neuromuscular and hormonal shifts, is the most pronounced. Squats with a barbell also demonstrated a significant increase (19.7%), while the bench press, being a more local exercise for the muscles of the upper limbs and chest, showed a slightly smaller, although very significant relative increase (19.6%). The statistically significant differences in the rates of progress between the exercises confirmed by the analysis of variance indicate the need to take into account the specifics of each exercise, its biomechanics and the degree of involvement of muscle masses when developing and individualizing strength programs.

The empirical data obtained in the course of the study and the conclusions made on their basis are of direct practical importance for improving the physical education system in higher education institutions and can

be used in developing modern scientifically based training programs. Promising areas for research may include: studying the long-term effects (over 24 weeks) of the proposed methodology on the physical fitness and health of students; comparative analysis of the effectiveness of various models of periodization of strength loads (for example, linear, wave-like, block) in academic settings; a more detailed study of gender differences in adaptive responses to strength training; studying the influence of concomitant factors (nutrition, daily routine, stress level) on the effectiveness of the training process; as well as an in-depth study of physiological and molecular biological mechanisms (for example, hormonal dynamics, gene expression, changes in the ultrastructure of muscle fibers).

Conclusions

A statistically high and practically significant superiority of the experimental training program, which includes the performance of basic strength exercises, over the standard university physical education program was established in the context of developing both maximum muscular strength and aerobic endurance. Participants in the experimental group demonstrated a significantly more pronounced increase in indicators in all three test exercises: bench press, squats with a barbell and deadlift compared to the results of students in CG. A similar divergence of adaptation trajectories was observed in relation to aerobic endurance, assessed by the distance covered in the Cooper 12-minute running test: in EG, an improvement of 17.3% was recorded compared to 7.2% in CG. The effect size calculated for intergroup differences in the increase in all key parameters consistently exceeded the threshold value of 1.2, which is categorized as a large practical effect and indicates that the observed differences are not just a statistical dependence, but reflect a real, pedagogically and physiologically significant advantage of the experimental approach.

One of the most important results of the study is the empirical confirmation of the phenomenon of a pronounced positive transfer of training from a program focused on the development of maximum strength to aerobic endurance indicators in individuals who did not have prior specialized sports training. This observation is of particular importance for optimizing training programs aimed at the harmonious development of physical qualities, especially under time pressure.

An integrated assessment of the data obtained clearly indicates that the experimental program, built on the basis of basic strength exercises, is highly effective and ensures the comprehensive development of students' physical qualities. Research in this area will further improve the scientific and methodological foundations of physical education and sports training, promoting health and increasing the level of physical fitness of young people.

Conflicts of interest. The authors declare no conflict of interest.

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