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The role of fitness programmes in the prevention of cardiovascular diseases among pupils in general secondary education institutions

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Abstract. The aim of the study was to determine the impact of a school fitness programme on the functional indicators of the cardiovascular system of pupils in general secondary education institutions. The study was conducted at Uman Lyceum No. 3 (Ukraine) from 31 March to 25 May 2025 and involved the implementation of an eight-week fitness programme with sequential measurements of pupils' cardiovascular system indicators to assess its effectiveness. It was found that the resting heart rate decreased from 84.6 ± 6.8 to 76.1 ± 6.2 beats per minute (-10%), indicating an increase in parasympathetic regulation. Systolic pressure decreased from 114.2 ± 8.5 to 110.4 ± 7.9 mm Hg (-3.3%), and diastolic pressure decreased from 72.8 ± 6.9 to 70.2 ± 6.4 mm Hg (-3.6%), indicating a decrease in peripheral resistance. At the same time, stroke volume increased from 70.4 ± 12.2 to 78.5 ± 11.8 ml (+11.5%), reflecting an improvement in the pumping function of the heart. A significant decrease in integral indicators was observed: the Robinson index decreased from 96.0 to 83.6 conventional units (-13%), the Ruffier index decreased from 10.8 to 8.6 conventional units (-20.4%), the functional change index from 2.87 to 2.41 conventional units (-16%) and the endurance coefficient from 20.7 to 17.4 conventional units (-15.9%) – indicated an increase in adaptive reserves and the effectiveness of cardiovascular system regulation. The data obtained confirmed that the eight-week fitness programme ensured the formation of stable aerobic adaptation, improvement of frequency and haemodynamic parameters, and an increase in cardiorespiratory reserves, which reduces the risk of early cardiovascular disorders. The results can be used by physical education teachers, school medical workers, and physical therapy specialists to develop and implement effective fitness programmes aimed at strengthening the cardiovascular health of children and adolescents in educational institutions

Keywords: cardiorespiratory adaptations; endurance; haemodynamic parameters; blood pressure; aerobic performance; adolescents; secondary school

Introduction

The incidence of cardiovascular disorders in the paediatric population shows a steady upward trend, which is associated with a decrease in daily physical activity and an increase in the prevalence of risk factors such as excess weight, high blood pressure and low exercise tolerance. According to the World Health Organization (2024), 81% of adolescents aged 11-17 do not meet the recommended level of daily physical activity (60 minutes of moderate or vigorous physical activity every day), which hinders the formation of stable adaptive responses of the cardiovascular system. The school environment is a key space for systematising physical activity, so insufficient attention to the implementation of targeted physical training programmes can contribute to a deterioration in functional indicators, an increase in cardiometabolic risks and the progression of early vascular changes.

Organised forms of physical activity in the school environment play an important role in the development of

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cardiorespiratory adaptations in children and adolescents. A randomised study conducted by C. Meng *et al.* (2022) found improvements in body composition and cardiorespiratory endurance after the introduction of a school programme of high-intensity interval training. In addition, a reduction in cardiometabolic markers in obese adolescents was demonstrated. An analysis of the impact of increased physical activity in the school environment conducted by T. Jagomast *et al.* (2023) showed a significant improvement in endothelial function and an increase in the physical performance of students. The scientists recorded positive dynamics in cognitive indicators, which is consistent with the strengthening of cardiovascular regulation mechanisms. According to D.V. Dychko *et al.* (2025), the effectiveness of a health-improving exercise complex for adolescents was confirmed by an improvement in haemodynamic parameters. In addition, the authors showed an increase in exercise tolerance. In children living in war conditions, after participating in a fitness programme, a decrease in heart rate (HR) and an improvement in overall physical condition were recorded, as shown in a study by A. Hakman *et al.* (2025). The authors noted the normalisation of a number of functional indicators of the cardiovascular system (CVS), confirming its positive adaptive response to training.

Intervention programmes within school physical education are considered a tool for preventing early vascular dysfunction in the paediatric population. A systematic review conducted by S.E. Neil-Sztramko *et al.* (2021) demonstrated an increase in physical activity levels and improved cardiorespiratory performance among students. The researchers recorded consistent positive effects in terms of improving overall physical fitness. The effectiveness of a randomised school exercise programme, demonstrated by S. Ketelhut *et al.* (2020), confirms that a targeted increase in physical activity at school contributes to lower blood pressure and improved vascular elasticity, reflecting an increase in exercise tolerance. Ukrainian scientific material confirms the effectiveness of multicomponent physiotherapy programmes, with V.E. Pyurko & S.M. Kazakova (2020) showing improvements in systemic signs of cardiovascular regulation in schoolchildren. The study proved the impact of comprehensive training approaches on the functional reserves of the body. Programmes aimed at students with cardiorespiratory disorders showed an increase in functional and adaptive indicators. In addition, the effectiveness of the comprehensive application of multidirectional physical training methods was confirmed.

A comprehensive assessment of the functional state of the cardiovascular system in schoolchildren allows to establish links between physical development, motor activity, and the risk of vascular disorders. A study of Ukrainian schoolchildren conducted by S. Kots *et al.* (2022) revealed abnormalities in heart rate and heart rate variability in children aged 11-12 years. A correlation between functional parameters and physical fitness was also found. Additional data on the circulatory characteristics of school-age pupils, provided by S. Kots & V. Kots (2023), demonstrated the variability of cardiovascular regulation depending on somatic characteristics, which emphasises the role of physical activity in stabilising haemodynamic reactions. In a scientific paper prepared by V. Ivanochko *et al.* (2024), a positive effect of differentiated physical training methods on the functional indicators of the cardiovascular system of female students aged 17-22 was recorded, which indicates the effectiveness of using multidirectional training approaches to improve the body's adaptive capabilities.

It should be noted that previous studies have not sufficiently revealed the impact of structured fitness programmes in the school environment on complex indicators of cardiovascular system functioning, focusing mainly on individual physiological parameters or short-term interventions. The aim of the study was to evaluate the effectiveness of a school fitness programme in improving the functional parameters of the cardiovascular system of learners. The objectives of the study were to develop a structured fitness programme for the school environment; to determine the baseline state of cardiorespiratory and haemodynamic indicators; to analyse changes in these parameters under the influence of the programme; and to establish relationships between the level of physical fitness and the dynamics of cardiovascular responses.

Materials and Methods

The study was organised as a quasi-experimental design with repeated measurements, which made it possible to trace the dynamics of pupils' cardiovascular system functional indicators under the influence of a structured fitness programme. The study was conducted at Uman Lyceum No. 3 (Uman, Cherkasy region), which provided the necessary conditions for the implementation of the fitness programme, screening measurements and repeated functional assessments. The educational institution has adequate sports infrastructure, including a sports hall, equipped playgrounds and the possibility of organising group classes within the framework of physical education lessons. The research stage lasted from 31 March to 25 May 2025, which was eight full weeks without breaks for holidays. The choice of this time and organisational interval was dictated by the need to ensure the continuity of the training process, minimise the impact of external educational and seasonal fluctuations, and allow sufficient time for the manifestation of primary cardiorespiratory and haemodynamic adaptations in school-age youth.

The study involved pupils from a general secondary school who were in grades 7-8. The total sample consisted of 42 pupils, including 21 boys (50.0%) and 21 girls (50.0%). The age range of the respondents was 12-14 years, with an average age of 13.1 ± 0.6 years. The choice of this age group was justified by the fact that this period is characterised by intensive formation of the cardiorespiratory system, which increases sensitivity to training influences; accordingly, it is at this age that changes in haemodynamic parameters and exercise tolerance are most pronounced (Meng *et al.*, 2022; Jagomast *et al.*, 2023). In addition, pupils in grades 7-8 are characterised by stable attendance and a sufficient level of physical fitness, which ensured the possibility of implementing a comprehensive eight-week fitness programme. The sample was formed using a special selection method, as all pupils from two parallel classes who met the medical and organisational criteria were involved. Information about participation was provided by class teachers and physical education teachers, who explained the structure, purpose and conditions of the study at parent-teacher meetings and class hours, after which parents provided written informed consent. The subjects were recruited directly at the educational institution, where students received explanations about the measurement procedure and participation in the fitness programme. The sample included pupils who belonged to the appropriate age group, had no contraindications to physical exercise, regularly attended physical education classes and were able to perform the proposed exercises. Children with acute or chronic diseases in the acute stage, cardiovascular pathologies that limit physical activity, orthopaedic limitations, a significant number of absences, or unwillingness to participate in the experiment were not included. Throughout the research period, the sample remained complete, and no participants were excluded before the end of the eight-week programme and final measurements.

No gender comparison was made, as the analysis was performed for a combined sample of pupils regardless of gender. The level of physical fitness of the participants at the time of inclusion in the study was heterogeneous: 12 pupils (28.6%) regularly attended sports clubs, the most common of which were football, volleyball and athletics. The remaining 30 pupils (71.4%) were limited to physical education classes and did not participate in additional training sessions. This difference in baseline physical activity was taken into account when planning the physical load, as the fitness programme provided for a universal basic level of intensity with the possibility of individual regulation of the pace and amplitude of movements. Further analysis was based on average values, which ensured a comprehensive reflection of the physiological characteristics of the group, regardless of the different levels of fitness of individual participants.

Description of the fitness program. The fitness program was developed taking into account the age and functional characteristics of students aged 12-14 and included a combination of aerobic, strength, coordination, and functional exercises aimed at developing cardiorespiratory adaptations. Classes were held three times a week as part of physical education lessons, with each lesson lasting 40-45 minutes. Each class included three structural components: preparatory, main, and final parts. A detailed description of the fitness program, including a list of exercises, their duration, mode of execution, and necessary equipment, is provided in Table 1.

Table 1. Structure of the fitness programme

Exercise content	Duration	Intensity / repetitions	Equipment
Warm-up section			
Jogging; walking with changes in pace; arm and leg swings; coordination exercises; mobilisation of the shoulder and hip joints	7-8 min	Moderate intensity, with a gradual increase in heart rate	No equipment
Main section (circuit training)			
A complex of 8-10 stations; a combination of strength, aerobic, and coordination exercises	28-32 min	30-40 seconds of work / 20-25 seconds of rest, 3 circuits	Mats, elastic bands, markers, gym benches
Squats (standard or with reduced range of motion for easier performance)	30-40 s	Steady pace	No equipment
Forward / backward lunges	30-40 s	Alternating legs	No equipment
Press-ups (full or with support on a bench)	30-40 s	8-15 repetitions depending on the level of physical fitness	Floor / bench
"Plank" (classic or knee-supported modification)	30-40 s	Static hold	Exercise mat
"Burpee" (full or simplified version)	30-40 s	Continuous execution	No equipment
Jumping jacks	30-40 s	Moderate pace	No equipment
Running on the spot with high knee lift	30-40 s	Maintenance of technique and pace	No equipment
Coordination exercises (stepping over markers, work on a coordination "ladder")	30-40 s	High pace with an emphasis on accuracy	Markers / coordination "ladder"
Concluding part			
Breathing exercises; static stretching of the main muscle groups (quadriceps, hamstrings, calf muscles, pectoral muscles)	4-5 min	Low intensity	Mats
Individual modifications			
Easier squats; press-ups with support; plank on the knees; reduced pace of aerobic exercises	-	As required by the pupils	Benches, mats

Source: made by the authors

The training load design strategy involved a gradual increase in intensity: during the first two weeks, emphasis was placed on technique and a moderate pace; in weeks 3-5, execution speed increased and rest intervals were shortened; and in weeks 6-8, alternating high and moderate intensities was applied to stimulate both aerobic and anaerobic components of endurance. Individualisation of the load was implemented in cases where pupils demonstrated lower tolerance to physical activity. Adjustments were made according to the pupils' capabilities and under continuous supervision by the teacher.

The programme was delivered by a physical education teacher at Uman Lyceum No. 3, who monitored correct technique, exercise safety, adherence to prescribed intensity and rest intervals, as well as the pupils' functional status. All pupils had free access to room-temperature drinking water in individual bottles and were allowed to drink according to personal need during the session, which supported hydration and helped prevent fatigue. Classes were conducted in the lyceum sports hall, ensuring appropriate sanitary, hygienic, and safety conditions for implementation of the fitness programme.

The functional state of the pupils' cardiovascular system was assessed in a comprehensive format, recording parameters at rest, during training sessions, and under conditions of cognitive load. All measurements were taken in the sports hall of Uman Lyceum No. 3 and in the school's medical office by the physical education teacher and the school nurse. Before each procedure, pupils underwent a ten-minute adaptation to a resting state. Comprehensive testing was performed three times: before the start of the program (week 0), during the intermediate period (week 4), and after the completion of the program (week 8). All recorded values of functional indicators within each measurement point were averaged after two consecutive measurements to minimise random error. At the same time, the heart rate indicators during training loads were recorded at each session, after which the average daily values for weekly dynamics were calculated and included in the analysis at the corresponding control points. Blood pressure (BP) was determined using the Korotkoff method with a mechanical tonometer AND UA-200 (Japan). Measurements were taken in a sitting position twice at two-minute intervals. Pulse pressure was calculated based on systolic blood pressure and diastolic blood pressure:

$$PP = BP_{max} - BP_{min}, \tag{1}$$

where PP – pulse pressure; BP_{max} – systolic blood pressure; BP_{min} – diastolic blood pressure. Heart rate was recorded using a Beurer PM 25 heart rate monitor (Germany) or by palpation of the radial artery. Based on heart rate and blood pressure values, the Robinson index was determined, which characterises the level of strain on the cardiovascular system:

$$RI = \frac{HR \times BPmax}{100}, \tag{2}$$

where RI – Robinson index; HR – heart rate; BP_{max} – systolic blood pressure. Functional reserves were assessed using the Ruffier test, which involved three measurements of heart rate: at rest, immediately after performing squats, and after one minute of recovery. The Ruffier index was calculated using the formula:

$$RI = \frac{4 \times (P1 + P2 + P3) - 200}{10}, \tag{3}$$

where RI – Ruffier index; $P1$ – heart rate at rest; $P2$ – heart rate immediately after exercise; $P3$ – heart rate after one minute of recovery; 200 – normative correction (integral threshold of the sum of heart rate values). In addition, the functional changes index (FCI) was determined, which integrates heart rate, blood pressure, and anthropometric characteristics, as well as the adaptive potential of the cardiovascular system, which characterises the effectiveness of regulatory mechanisms. The endurance coefficient was calculated using Kvas's formula:

$$EC = \frac{HR \times 100}{BP_{max} - BP_{min}}, \tag{4}$$

where EC – endurance coefficient; HR – heart rate during recovery (after 1 or 2 minutes following exercise); BP_{max} and BP_{min} – blood pressure values. Stroke volume (SV) was determined using an empirical formula recommended for the adolescent age group:

$$SV = PP \times 1.7, \tag{5}$$

where SV – systolic (stroke) blood volume, ml; PP – pulse pressure, mmHg; 1.7 – empirical age-related coefficient. Based on the calculated SV value, cardiac output (CO) was determined using the formula:

$$CO = SV \times HR, \tag{6}$$

where CO – cardiac output, ml/min; SV – stroke volume, ml; HR – heart rate per minute. The SV and CO indicators reflected the efficiency of the heart's pumping function and the dynamics of haemodynamic adaptations in response to physical exercise. Cardiac activity indicators during training sessions were recorded using Xiaomi Mi Band 7 (China) fitness bracelets equipped with an optical photoplethysmography sensor. HR was recorded at the fifth, fifteenth and final minutes of the main part of the training session, as well as one minute after the completion of the exercises using the circuit training method to assess the speed of recovery. The indicators were recorded by the physical education teacher, who read the information from the bracelet screens and entered it into the control observation protocols. The combination of all these indicators provided a comprehensive assessment of the functional state of the pupils' cardiovascular system, covering haemodynamic parameters, adaptive reserves and the immediate physiological response to exercise.

For the correct interpretation of the data obtained, generally accepted age standards for adolescents aged 12-14 were used. The normal range of heart rate at rest is 60-100 beats per minute, depending on the level of physical activity, while the optimal blood pressure values are 105-125 mmHg for BP_{max} and 65-80 mm Hg for BP_{min}. Pulse pressure is usually within the range of 30-50 mmHg. The Robinson index in this age group corresponds to the functional optimum at values of 70-90 conventional units, and the Ruffier index assesses functional reserves as good at values < 6 conventional units, average at 6-10, and satisfactory at 10-15. For the functional change index, values of 2.0-2.5 are considered optimal, and 2.6-3.0 are considered borderline. The endurance coefficient is favourable at values <17 conventional units, average at 17-20, and reduced at >20. The norm for systolic blood volume is 65-90 ml, and for cardiac output – 4.5-6.5 l/min, which corresponds to the typical limits of age-related cardiorespiratory performance.

Statistical data processing. Statistical data processing was performed using IBM SPSS Statistics 29.0 software. Descriptive statistics were presented as mean and standard deviation ($M \pm SD$). The dynamics of indicators at three control points (at 0, 4, and 8 weeks) were assessed using repeated measures analysis of variance (Repeated Measures ANOVA) or the Friedman test for abnormal distribution. Paired comparisons between stages were performed using Student's t test for dependent samples or Wilcoxon's test. In addition to the absolute values of the indicators, the results also included the relative change (Δ), which was defined as the difference between the values at weeks 8 and 0, expressed as a percentage of the baseline level. This indicator allowed for a quantitative assessment of the intensity of the training effect and ensured the comparability of changes between different physiological parameters. Correlation analysis was performed using Pearson's or Spearman's coefficients, depending on the nature of the distribution. The level of statistical significance was set at $p < 0.05$.

The study complied with ethical standards for working with minors and was conducted in accordance with the European Commission's Guidelines on Ethics and Data Protection (European Commission, 2021) and the ICC/ESOMAR International Code of Market, Public and Social Research (2025). The study was approved by the administration of Uman Lyceum No. 3. The participation of pupils was voluntary and confirmed by the written informed consent of their parents, who received the necessary information about the content of the programme, the workload and the procedure for processing personal data. During the study, safety measures, pedagogical and medical supervision were provided, and all personal and physiological data were stored in an anonymised form on secure media in accordance with European requirements for ethics and confidentiality. Pupils had the right to withdraw from participation at any time without any consequences for the educational process.

Results

Baseline indicators of the functional state of the cardiovascular system of pupils

The baseline cardiovascular indicators of the pupils demonstrated a combination of normative haemodynamic values and markers of insufficient training, which is typical of adolescents with irregular physical activity. The integral and calculated indices obtained using formulas (1-6) reflected moderate myocardial strain, low efficiency of heart rate regulation, and a borderline level of functional reserves. The summarised results are presented in Table 2.

Table 2. Baseline indicators of the functional state of the cardiovascular system of pupils ($n = 42$)

Indicator	$M \pm SD$	Interpretation relative to normative values
HR, beats/min	84.6 ± 6.8	within the normal range
BP_{max}, mmHg	114.2 ± 8.5	within the normal range
BP_{min}, mmHg	72.8 ± 6.9	within the normal range
PP, mmHg	41.4 ± 7.2	within the normal range
Robinson index, conventional units	96.0 ± 11.3	increased myocardial strain
Ruffier index, conventional units	10.8 ± 1.9	borderline level of reserves
Functional changes index, conventional units	2.87 ± 0.41	borderline level of adaptation
EC, conventional units	20.7 ± 3.9	lower endurance (values above the normative range)
SV, ml	70.4 ± 12.2	lower limit of the normal range
Cardiac output, ml/min	5,948 ± 1,010	within the normal range, high variability

Source: compiled by the authors

The obtained results indicate that the baseline physiological state of the pupils' cardiovascular system corresponded to age-related norms in terms of the main hemodynamic indicators; however, it was characterised by a number of markers of insufficient training. This is typical for children aged 12-14 years who do not participate in regular sports activities and receive only standard physical load within the school curriculum. The first indicator of cardiovascular system fitness is resting heart rate. The mean heart rate value was 84.6 ± 6.8 beats per minute, which corresponds to the age norm. Such values are most often observed in schoolchildren with a reduced level of aerobic fitness, when the cardiac muscle works less economically and the activity of the sympathetic division of the autonomic nervous system predominates over the parasympathetic one. In sports physiology, such characteristics are considered a potential prerequisite for a pronounced training effect, since regular exercise leads to a reduction in resting heart rate and an increase in heart rate variability (Meng *et al.*, 2022). Blood pressure indicators demonstrated the absence of hypertensive or hypotensive deviations in the group: the mean systolic blood pressure value was 114.2 ± 8.5 mmHg, and diastolic blood pressure was 72.8 ± 6.9 mmHg. These data are consistent with age-related norms; however, significant variability in diastolic pressure may indicate different degrees of structural maturity of the vascular bed, which is characteristic of adolescents during a period of intensive somatic growth. Pulse pressure (41.4 ± 7.2 mmHg) was within the physiological norm and indicated preserved elasticity of the arterial wall. However, variability was also substantial in this parameter, which points to heterogeneity of vascular reactivity within the studied cohort.

A deeper characterisation of cardiac hemodynamics is provided by the Robinson index, which reflects the level of myocardial tension at rest. Its values (96.0 ± 11.3 conventional units) exceeded the optimal range, indicating increased functional load on the heart even in the absence of physical exertion. Such values are typical for children with low aerobic endurance or increased psycho-emotional stress, which may also cause activation of the sympathetic nervous system. The Ruffier index (10.8 ± 1.9 conventional units), which assesses the ability of the cardiovascular system to adapt to physical load and recover after it, corresponded to a borderline level. This means that adaptive reserves in most pupils were average or below average. These trends are further confirmed by the Functional Changes Index (2.87 ± 0.41 conventional units), the values of which are characteristic of insufficiently trained children and indicate a reduced level of regulatory capabilities of the cardiovascular system.

The endurance coefficient (20.7 ± 3.9 conventional units) was also higher than optimal. Since, according to the Kvas method, higher endurance coefficient values indicate lower endurance, these results point to insufficient physical capacity of the pupils. In physical education and sports practice, this is considered an important argument for the appropriateness of using programmes aimed at developing general endurance. Indicators of the heart's pumping function – systolic and cardiac output – complement the overall characterisation of physiological status. SV (70.4 ± 12.2 ml) was at the lower limit of the age norm, indicating relatively low contractile strength of the left ventricle. Cardiac output (5,948 ± 1,010 ml/min), although within the normal range, demonstrated substantial variability, which indicates differences in aerobic potential among pupils.

Since the analysis was performed on the basis of arithmetic mean values of functional indicators obtained from the entire sample of pupils, the identified profile of the baseline state of the cardiovascular system reflected a general tendency toward insufficient training, typical of adolescents with a predominantly sedentary lifestyle. Despite individual differences in the level of daily physical activity, the integrated mean values indicated a combination of normative blood pressure and cardiac output parameters with borderline and strained adaptation indicators, specifically elevated heart rate, a high Robinson index, a borderline Ruffier index, lower stroke volume, and an increased endurance coefficient. Such an averaged physiological profile confirmed an insufficient level of cardiorespiratory fitness and limited reserve capacities of the cardiovascular system, which created prerequisites for the formation of pronounced positive adaptive changes under the influence of a structured fitness programme.

Changes in indicators at the fourth week of fitness programme implementation

The interim assessment of the functional state of the pupils' cardiovascular system at the fourth week of the fitness programme made it possible to identify early training adaptations that develop in response to systematic physical loads. The first four weeks represent a period of initial physiological restructuring, during which neurohumoral mechanisms are normalised, myocardial strain is reduced, and vascular tone improves (Baumgartner *et al.*, 2020). As the analysis was based on averaged group values, the results presented in Table 3 reflect the integral response of the pupils' cardiovascular system to the physical training programme. The calculated parameters were determined using formulas (1-6).

Table 3. Cardiovascular system indicators at the fourth week of the experiment ($n = 42$)

Indicator	Week 4 ($M \pm SD$)	Change from baseline
HR, beats/min	80.2 ± 6.1	↓ 5.2%
BPmax, mmHg	112.5 ± 8.1	↓ 1.7 mmHg
BPmin, mmHg	71.5 ± 6.4	↓ 1.3 mmHg
PP, mmHg	41.0 ± 7.0	↓ 0.4 mmHg
Robinson index, conventional units	89.9 ± 10.2	↓ 6.4%
Ruffier index, conventional units	9.5 ± 1.7	↓ 12.0%
Functional changes index, conventional units	2.65 ± 0.38	↓ 7.7%
EC, conventional units	19.1 ± 3.4	↓ 7.7%
SV, ml	74.2 ± 11.5	↑ 5.4%
Cardiac output, ml/min	5,940 ± 998	↓ 0.1%

Source: compiled by the authors

Interim results indicate the formation of early positive adaptations of the cardiovascular system in response to regular fitness training. The most noticeable change was in resting heart rate, which decreased from 84.6 to 80.2 beats per minute ($p < 0.05$). A 5.2% decrease in HR indicates increased vagal control and decreased basal sympathetic influence, which is a marker of improved cardiac efficiency. In pedagogical physiology, this change is one of the most sensitive indicators of early training adaptation, since HR is the first to respond to systematic aerobic exercise. Blood pressure indicators changed less significantly, which corresponds to the typical physiological response of adolescents during training. Systolic pressure decreased to 112.5 ± 8.1 mm Hg ($p < 0.05$), indicating a decrease in peripheral vascular resistance and improved elasticity of the arterial bed. Diastolic pressure showed a slight, statistically insignificant decrease ($p > 0.05$), which is typical for the initial phase of adaptation, when central haemodynamic mechanisms change faster than peripheral ones. Pulse pressure remained stable (41.0 mm Hg), indicating no significant changes in vascular stiffness and stroke volume at this stage of the programme. This was expected, as structural changes in the arterial wall and significant changes in stroke volume are mainly formed after 6-10 weeks of training.

A decrease in the Robinson index to 89.9 ± 10.2 conventional units ($p < 0.05$) reflected a reduction in myocardial tension and a decrease in the heart's oxygen demand at rest. This reaction is critically important for pupils with borderline or elevated baseline Robinson index values, as it reflects the transition of the cardiovascular system to a more economical mode of functioning. The decrease in the Ruffier index was particularly pronounced, from 10.8 to 9.5 conventional units ($p < 0.01$). The Ruffier index is one of the indicators of adaptation to physical activity, as it integrates three HR values: before exercise, immediately after exercise, and after one minute of recovery. An improvement in Ruffier index indicates faster heart rate recovery, increased myocardial contractility, and reduced metabolic stress. In fact, it is one of the most important markers of endurance progress in school age. A decrease in the functional change index to 2.65 ± 0.38 cond. units ($p < 0.05$) reflects the improvement of the regulatory mechanisms of the cardiovascular system and improved adaptation to physical activity. The FCI responds to training more slowly than the HR or Robinson index, so its early changes indicate a high potential for further positive adaptations.

The endurance coefficient decreased from 20.7 to 19.1 conventional units ($p < 0.05$), indicating an improvement in the body's aerobic capacity. According to Kvas's methodology, lower EC values are a sign of more efficient heart function during physical activity. This emphasises that even during the first four weeks of the programme, significant improvements in recovery speed and overall resistance to exercise were observed. The indicators of the heart's pumping function showed positive trends: systolic blood volume increased by 5.4% ($p<0.05$), which means an increase in the force of heart contractions. Minute blood volume remained virtually unchanged ($p > 0.05$), due to the compensatory relationship between SV and HR: the decrease in heart rate was compensated by an increase in stroke volume. This mechanism is characteristic of the economisation of heart activity during the early phases of aerobic adaptation.

Summarising the results, it can be noted that the fourth week was a stage of formation of early stable adaptations of the cardiovascular system. The decrease in HR and Robinson's index reflected a decrease in myocardial tension and an increase in the efficiency of cardiac activity, while the improvement in the Ruffier index and endurance coefficient indicated a strengthening of functional reserves and faster recovery after exercise. The increase in stroke volume demonstrated an improvement in the efficiency of the heart's pumping function, and stable blood pressure and pulse pressure readings confirmed a balanced vascular response. Taken together, these changes indicate that by the fourth week, the pupils' bodies had transitioned to a more economical and coordinated cardiovascular system, laying the foundation for further progress in the final stage of the programme.

Final dynamics of indicators after the eighth week

The final stage of the eight-week fitness programme demonstrated the most pronounced adaptive changes in the functioning of the pupils' cardiovascular system, indicating a transition from the stage of initial responses to a phase of structured and stable physiological adaptation. Analysis of the final indicators made it possible to assess the magnitude of the training effect, the sequence of changes, and their functional significance. All presented results reflect averaged sample values (calculated using formulas (1-6)) and include a statistical comparison between the baseline stage (week 0) and the completion of the programme (week 8) (Table 4). For an in-depth interpretation of the overall trajectory of cardiovascular system adaptations, key integral indicators of fitness – resting heart rate, Robinson index, and Ruffier index – were graphically represented at three control points (0, 4, and 8 weeks). The combined presentation of these three indicators allows for a comprehensive assessment of changes in autonomic regulation, myocardial economy, and recovery capacity. The graphical dynamics allow for a visual comparison of the speed and direction of changes, which were mathematically confirmed by statistical analysis ($p < 0.001$) (Fig. 1).

Table 4. Final dynamics of cardiovascular system indicators after eight weeks of the programme ($n = 42$)

Indicator	Week 0 $M \pm SD$	Week 8 $M \pm SD$	Δ change (%)	p
HR, beats/min	84.6 ± 6.8	76.1 ± 6.2	-10.0%	< 0.001
BPmax, mmHg	114.2 ± 8.5	110.4 ± 7.9	-3.3%	= 0.041
BPmin, mmHg	72.8 ± 6.9	70.2 ± 6.4	-3.6%	= 0.038
PP, mmHg	41.4 ± 7.2	40.2 ± 6.8	-2.9%	= 0.112
Robinson index, conventional units	96.0 ± 11.3	83.6 ± 10.4	-13.0%	< 0.001
Ruffier index, conventional units	10.8 ± 1.9	8.6 ± 1.5	-20.4%	< 0.001
Functional changes index, conventional units	2.87 ± 0.41	2.41 ± 0.38	-16.0%	< 0.001
EC, conventional units	20.7 ± 3.9	17.4 ± 3.3	-15.9%	< 0.001
SV, ml	70.4 ± 12.2	78.5 ± 11.8	+11.5%	< 0.001
Cardiac output, ml/min	5,948 ± 1,010	5,975 ± 980	+0.5%	= 0.612

Source: compiled by the authors

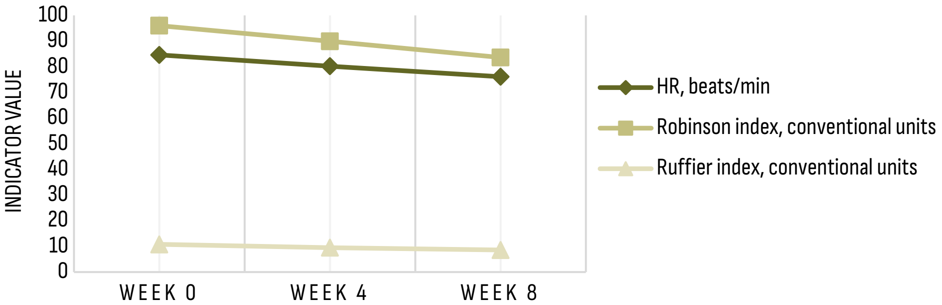

Figure 1. Dynamics of heart rate, the Robinson index, and the Ruffier index

Source: created by the authors based on the received data

Figure 1 shows a consistent and pronounced decrease in all three indicators over the eight-week period. The heart rate curve demonstrates a steady reduction from 84.6 to 76.1 beats per minute, reflecting the development of a more economical mode of cardiac function and enhanced parasympathetic regulation. The parallel decrease in the Robinson index (-13%) confirms a reduction in myocardial strain and an increase in stroke volume. The most rapid dynamics are observed for the Ruffier index (-20.4%), indicating improved recovery capacity and adaptation to physical load. Taken together, these changes indicate that the cardiovascular system shifted to a more efficient mode of functioning, characteristic of the development of stable aerobic adaptation. As haemodynamic parameters are among the most sensitive markers of adaptation to physical exercise, a graphical comparison of systolic blood pressure, diastolic blood pressure, and pulse pressure was performed across three time points. This comprehensive presentation makes it possible to assess not only changes in pressure values but also their interaction, including the degree of peripheral resistance, vascular wall stability, and arterial elasticity (Fig. 2).

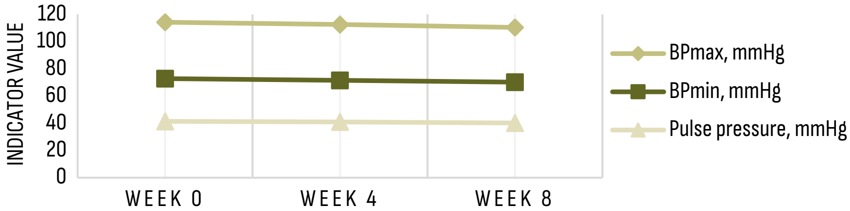

Figure 2. Dynamics of BP_{max}, BP_{min}, and pulse pressure
Source: created by the authors

The graphical data demonstrate a gradual decrease in BPmax and BPmin, indicating an improvement in vascular tone and optimisation of haemodynamics. A moderate reduction in systolic blood pressure (-3.3%) and diastolic blood pressure (-3.6%) reflects a decrease in total peripheral resistance, which is characteristic of pupils who begin to engage in regular physical exercise. Pulse pressure, by contrast, remains stable, confirming the absence of excessive load on the arterial wall and normal vascular elasticity. Such stability is an important indicator of safe adaptation to training loads in adolescents. To assess the efficiency of cardiac output and the heart's ability to maintain an adequate level of systemic perfusion, a graphical comparison of stroke volume, cardiac output, and the endurance coefficient was performed. The combination of these indicators within Figure 3 makes it possible to identify the relationship between stroke volume, heart rate, and the overall efficiency of the myocardium's pumping function.

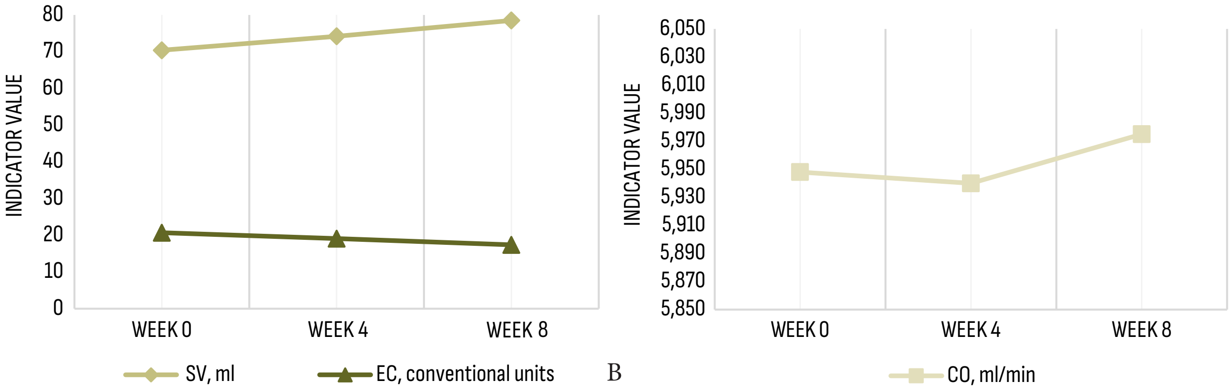

Figure 3. Dynamics of stroke volume, endurance coefficient (A), and cardiac output (B)
Source: created by the authors

In Figure 3, it is clearly evident that stroke volume increased progressively (+11.5%), reflecting an enhancement of myocardial contractile capacity and improved peripheral circulation. Cardiac output remained relatively stable, as the increase in stroke volume compensated for the decrease in heart rate, which represents a typical mechanism of an adapted cardiovascular system. At the same time, the reduction in the endurance coefficient (-15.9%) indicates an increase in aerobic efficiency and a more economical functioning of the heart, resulting from systematic training exposure.

The dynamics of physiological indicators over the eight-week period convincingly confirmed the presence of a pronounced training effect. A consistent decrease in frequency-based and integrated indicators (HR, Robinson index, Ruffier index, FCI, and EC), alongside a simultaneous increase in stroke volume, indicated a gradual strengthening of parasympathetic regulation, economisation of myocardial activity, and improvement in recovery processes. Reduced cardiovascular strain, enhanced recovery capacity, and improved aerobic performance reflect the classical physiological mechanism of adaptation to regular training loads during adolescence. Importantly, even integral regulatory indices, which typically change more slowly, demonstrated statistically significant improvements, confirming the stability and sufficient intensity of the training stimulus provided by the school-based fitness programme. The combination of these adaptive changes indicates not only an increase in current functional capacity but also the development of a preventive potential with respect to reducing the risk of future cardiovascular diseases, including primary arterial hypertension, early forms of endothelial dysfunction, and disturbances of autonomic regulation of heart rhythm.

In summary, the final data indicate that the eight-week fitness programme ensured a harmonised and safe adaptation of the pupils' cardiovascular system. An increase in stroke volume under conditions of stable cardiac output, together with a moderate reduction in arterial blood pressure, reflects optimisation of both central and peripheral circulatory mechanisms. At the same time, the stability of pulse pressure confirms the absence of excessive vascular load. The overall pattern of adaptations – from a reduction in heart rate to improvements in regulatory indices – points to a transition of the cardiovascular system to a more economical, stable, and productive mode of functioning. Thus, the programme demonstrated high effectiveness in enhancing physiological reserves, aerobic capacity, and overall cardiorespiratory resilience of schoolchildren.

Discussion

The results of the study demonstrated a clear positive trend in the cardiovascular performance of pupils during the eight-week fitness programme. The most pronounced changes were observed in heart rate, Robinson and Ruffier indices, endurance coefficient and systolic blood volume, while arterial and pulse pressure underwent moderate corrections. The final values obtained indicate the formation of a holistic favourable dynamics of haemodynamic and regulatory parameters, which creates the basis for further scientific analysis and interpretation of the mechanisms of the identified changes.

The results obtained showed a significant decrease in the frequency and regulatory indicators of the cardiovascular system: HR decreased from 84.6 ± 6.8 to 76.1 ± 6.2 beats/min (-10.0%), the Robinson index decreased from 96.0 ± 11.3 to 83.6 ± 10.4 conventional units (-13.0%), and the Ruffier index decreased from 10.8 ± 1.9 to 8.6 ± 1.5 conventional units (-20.4%). Such consistent dynamics of the three integral parameters indicated the formation of a more economical heart function, enhanced vagus-mediated regulation, and accelerated recovery reactions during physical activity. Observations by D.M. Cooper & S. Radom-Aizik (2020) also confirmed that systematic physical activity activated the mechanisms of vagus-mediated control of cardiac activity, which led to a decrease in HR at rest. The authors emphasised the role of immunometabolic adaptations, which further confirms the similarities of the mechanisms recorded in this study. The results of S. Ibrahim *et al.* (2020) showed that participation in school fitness programmes reduced myocardial workload, which coincides with the downward trajectory of the Robinson index. At the same time, the scientists noted that the magnitude of the changes depended on the regularity of the classes, which explains the correspondence with the observed rates of Robinson index reduction.

The consistent reduction in HR and integral markers of regulation was consistent with the mechanisms of parasympathetic activation. A similar pattern was also reported in the work of W. Budts *et al.* (2020), where autonomic regulation indicators changed in the direction of decreasing frequency load, which coincides with the observed decrease in HR and Robinson index. A stable decrease in HR over eight weeks correlates with the criteria for early aerobic adaptation formulated in the source by L.A. Kaminsky *et al.* (2022), where it was emphasised that even moderate-intensity training causes similar cardiorespiratory changes. At the same time, the less pronounced decrease in frequency indicators described in the study by A.S. Perry *et al.* (2023) does not fully coincide with the identified trajectory, which may indicate different program structures or varying levels of pupil involvement. The same study also pointed out that the lack of clear regularity reduces the effectiveness of adaptation, which contrasts with the more pronounced dynamics of HR and Ruffier index reduction.

After eight weeks, a decrease in systolic pressure from 114.2 ± 8.5 to 110.4 ± 7.9 mm Hg (-3.3 %) and diastolic pressure from 72.8 ± 6.9 to 70.2 ± 6.4 mm Hg (-3.6%), while pulse pressure decreased moderately (-2.9%) and without statistical significance. This dynamic reflects an improvement in vascular tone and a decrease in peripheral resistance, which is characteristic of early adaptive responses to regular physical activity. A systematic review by M. Peralta *et al.* (2020) demonstrated that increased physical activity in school settings contributed to the normalisation of blood pressure, which conceptually corresponds to the decrease in systolic and diastolic components observed in this sample. The authors emphasised that the effect was evident even at moderate exercise intensities, consistent with the moderate but stable dynamics of diastolic pressure. A meta-analysis by E. Norris *et al.* (2020) showed that active school interventions contributed to a decrease in systolic pressure in children, which coincides with the BP_{max} trend. In addition, an improvement in the overall haemodynamic profile was noted, which correlates with the stability of pulse pressure in conditions of increased physical activity. A global comparative study by R. Uddin *et al.* (2020) found that participation in physical education classes was associated with a decrease in peripheral resistance, corresponding to a decrease in BP_{min}. Scientists have pointed out that regular physical activity enhances vascular wall reactivity, which coincides with a decrease in diastolic pressure. The authors N.C. Bagatini *et al.* (2023) proved that an increase in cardiorespiratory fitness was accompanied by a decrease in blood pressure in schoolchildren, and this pattern is consistent with the recorded decrease in BPmax. At the same time, the results of G. Pepera *et al.* (2022) demonstrated slower dynamics in children with low baseline physical activity, which contrasts with the more pronounced changes obtained after an eight-week intervention, thus emphasising the effectiveness of a structured exercise programme.

Stroke volume increased from 70.4 ± 12.2 to 78.5 ± 11.8 ml (+11.5%), cardiac output remained at a stable level (+0.5%), and the endurance coefficient decreased from 20.7 to 17.4 units (-15.9%). This pattern of changes reflects an increase in myocardial contractility and a transition of the cardiovascular system to a more economical mode of operation. A study by L. Marković *et al.* (2022) found that an increase in stroke volume is a key morphofunctional response of adolescents to regular training stimuli, and this pattern is fully consistent with the increase in SV in the data presented. The researchers emphasised that a decrease in frequency characteristics accompanies an increase in stroke volume, which structurally coincides with a decrease in EC. The work of J.F.D.C. Silveira *et al.* (2020) showed that even moderate physical activity improves central haemodynamics, in particular due to an increase in stroke volume, which fully correlates with the observed upward dynamics of SV. The researchers emphasised that the stability of minute blood volume under conditions of increased stroke volume reflects an economised mode of heart function, which corresponds to the constancy of CO. In a randomised school intervention described by R.S. Matos *et al.* (2020), improved perfusion and reduced haemodynamic load were found, which correlates with a decrease in EC as an indicator of increased aerobic efficiency. Similarly, J. Domaradzki *et al.* (2025) confirmed that eight-week training protocols significantly improve the aerobic performance of adolescents, which is comparable to a decrease in the endurance coefficient. According to M.A. Hassan *et al.* (2024), the optimal training effect on the pumping function of the heart is formed under conditions of moderate intensity load, and this model corresponds to the stability of CO in combination with an increase in stroke volume.

The final dynamics of the parameters showed a change in most indicators in the range of 10-20%, including a decrease in in the Robinson index, the Ruffier index, the index of functional changes, and the endurance coefficient, as well as an increase in stroke volume, which indicates the formation of aerobic adaptation and restructuring of cardiovascular regulation. The combination of these changes demonstrates the harmonisation of central and peripheral mechanisms characteristic of an increase in the reserve capacity of the myocardium and vascular bed. A study by L. Baumgartner *et al.* (2020) found that regular physical activity contributes to the improvement of vascular structure and functional capacity of the arterial bed, which is consistent with the stability of pulse pressure as a marker of adequate vascular elasticity. The authors pointed out that improved endothelial regulation reduces myocardial stress, which is fully consistent with a decrease in the Robinson index. A study by J.R. Lopez *et al.* (2020) showed that regular physical activity can improve vascular elasticity even in children with cardiac conditions. A similar mechanism is reflected in a gradual decrease in systolic and diastolic pressure as a marker of normalisation of peripheral resistance. The work of J.M. Nagata *et al.* (2022) emphasises that maintaining physical activity from a young age is associated with a reduced risk of early cardiovascular events, and the resulting complex of adaptive haemodynamic changes demonstrates precisely the direction of preventive action described in this study. Analytical data from B.A. Franklin *et al.* (2022) emphasised the decisive role of aerobic performance in reducing myocardial load, which is reflected in a decrease in the endurance coefficient as an integral marker of cardiac economy. In addition, a study by M.N. Ahmadi *et al.* (2022) proved that even relatively small amounts of intense physical activity contribute to improving the cardiometabolic profile. This pattern is confirmed by a coordinated increase in functional reserves and optimisation of key indicators of the cardiovascular system.

The final interpretation of the data obtained showed that the dynamics of cardiovascular system indicators correspond to typical models of aerobic adaptation in adolescents described in scientific studies. The decrease in frequency and integral indices, the increase in stroke volume, and the optimisation of haemodynamics are consistent with evidence of improved autonomic regulation, vascular function, and cardiac pump capacity under the influence of regular physical activity. The combination of results confirms the effectiveness of school fitness programmes as an effective tool for the preventive strengthening of cardiovascular health.

Conclusions

The baseline characteristics of the cardiovascular system indicated a moderate level of fitness among the pupils, with evident signs of strain in regulatory mechanisms. Heart rate was within the age-related norm (84.6 ± 6.8 beats/min), the Robinson index was elevated (96.0 ± 11.3 conventional units), and the Ruffier index corresponded to a borderline level (10.8 ± 1.9 conventional units), indicating insufficient adaptation to physical load. Systolic and diastolic blood pressure remained within normal limits (114.2 ± 8.5 and 72.8 ± 6.9 mmHg, respectively), while stroke volume was at the lower limit of the physiological range (70.4 ± 12.2 ml). Taken together, these indicators suggested a clear potential for the development of a pronounced training response under the influence of a structured fitness programme. The interim assessment at the fourth week indicated the initial phase of aerobic adaptation and normalisation of regulatory responses. HR decreased to 80.2 ± 6.1 beats/min (-5.2%), the Robinson index to 89.9 ± 10.2 conventional units (-6.4%), and the Ruffier index to 9.5 ± 1.7 conventional units (-12.0%). Changes in blood pressure were moderate in nature (BP_{max} -1.7 mmHg; BP_{min} -1.3 mmHg), pointing to early optimisation of peripheral resistance. SV increased to 74.2 ± 11.5 ml (+5.4%), while cardiac output remained stable. This pattern of changes confirmed the transition from initial compensatory responses to the formation of stable aerobic restructuring of the cardiovascular system.

After completion of the eight-week programme, the most pronounced adaptive changes were recorded, reflecting the full establishment of an economical and efficient mode of cardiovascular functioning. HR decreased to 76.1 ± 6.2 beats/min (-10.0%), the Robinson index to 83.6 ± 10.4 conventional units (-13.0%), and the Ruffier index to 8.6 ± 1.5 conventional units (-20.4%). The endurance coefficient decreased by 15.9%, while stroke volume increased to 78.5 ± 11.8 ml (+11.5%). Systolic and diastolic blood pressure decreased moderately (-3.3% and -3.6%, respectively), whereas cardiac output remained stable. These changes indicated completion of the transition to stable aerobic adaptation and optimisation of haemodynamics. The observed dynamics of the indicators are consistent with the structure of the study, which involved development of a fitness programme, assessment of baseline status, analysis of adaptive responses, and identification of regulatory changes in the cardiovascular system. Thus, the results comprehensively characterise the effectiveness of the programme and confirm its capacity to enhance the cardiorespiratory reserves of schoolchildren. The recorded improvements point to a potential preventive effect in terms of early reduction of the risk of cardiovascular regulatory disorders in adolescence, indicating full achievement of the study aim.

A limitation of the study was the relatively small sample size and inclusion of only one age group, which restricts the generalisation of the findings to a broader school population. Future research should expand the sample size, include several age cohorts, and apply randomised comparative designs to allow more precise identification of the characteristics and mechanisms of cardiovascular adaptation to structured fitness programmes.

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Conflict of Interest

None.

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Роль фітнес-програм у профілактиці серцево-судинних захворювань учнів закладів загальної середньої освіти

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Анотація. Метою дослідження було визначити вплив шкільної фітнес-програми на функціональні показники серцево-судинної системи учнів закладів загальної середньої освіти. Дослідження проведено на базі Уманського ліцею № 3 (Україна) у період із 31 березня до 25 травня 2025 року та передбачало реалізацію восьмитижневої фітнес-програми з послідовними вимірюваннями показників серцево-судинної системи учнів для оцінки її ефективності. Було встановлено, що частота серцевих скорочень у спокої зменшилася з 84,6 ± 6,8 до 76,1 ± 6,2 уд/хв (-10 %), що вказує на посилення парасимпатичної регуляції. Систолічний тиск знизився з 114,2 ± 8,5 до 110,4 ± 7,9 мм рт. ст. (-3,3 %), а діастолічний – з 72,8 ± 6,9 до 70,2 ± 6,4 мм рт. ст. (-3,6 %), що свідчить про зменшення периферичного опору. Водночас ударний об'єм крові зріс із 70,4 ± 12,2 до 78,5 ± 11,8 мл (+11,5 %), що відображає покращення насосної функції серця. Досліджено, що значне зниження інтегральних показників – індексу Робінсона з 96,0 до 83,6 ум. од. (-13 %), індексу Руф'є з 10,8 до 8,6 ум. од. (-20,4 %), індексу функціональних змін з 2,87 до 2,41 ум. од. (-16 %) та коефіцієнта витривалості з 20,7 до 17,4 ум. од. (-15,9 %) – засвідчило підвищення адаптаційних резервів і ефективності регуляції серцево-судинної системи. Отримані дані підтвердили, що восьмитижнева фітнес-програма забезпечила формування стійкої аеробної адаптації, покращення частотних і гемодинамічних параметрів та підвищення кардіореспіраторних резервів, що зменшує ризик ранніх серцево-судинних порушень. Результати можуть бути використані вчителями фізичної культури, шкільними медичними працівниками та фахівцями з фізичної терапії для розроблення та впровадження ефективних фітнес-програм, спрямованих на зміцнення серцево-судинного здоров'я дітей і підлітків у закладах освіти

Ключові слова: кардіореспіраторні адаптації; витривалість; гемодинамічні параметри; артеріальний тиск; аеробна продуктивність; підлітки; основна школа