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Dynamics of physical development and functional capacity in youth aged 17-20 under the influence of aerobics

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Abstract. This study aimed to identify the characteristics of changes in indicators of physical development and functional capacity in young people resulting from the implementation of a specially designed aerobic programme. The research was conducted at Hryhorii Skovoroda University in Pereiaslav (Kyiv Region) over a ten-week period (3 February – 13 April 2025) and involved 40 students aged 17-21 years. The experimental design included three stages of measurement, which enabled an assessment of the dynamics of morphological and functional indicators in students under the influence of a structured aerobic training programme. The findings demonstrated a reduction in body mass by 1.1 kg, body mass index by 0.5 kg/m^2, waist circumference by 1.8 cm, and body fat percentage by 1.5%, indicating a decrease in central adiposity and optimisation of the somatic profile. Indicators of cardiovascular regulation also improved: resting heart rate decreased by 4.8 beats per minute, systolic blood pressure by 3.9 mmHg, and diastolic blood pressure by 2.5 mmHg, while the rate of heart rate recovery increased by 5.1 beats per minute. The Ruffier-Dixon index decreased by 3.8 points, reflecting enhanced reactivity and recovery capacity. Measures of physical fitness showed positive dynamics: the distance covered in the six-minute run increased by 154 m, standing long jump performance improved by 8.2 cm, muscular endurance increased by 4.1 repetitions, and the time for the 4×9 m shuttle run improved by 0.58 s. The set of observed changes confirms the effectiveness of the aerobic programme as a means of enhancing the overall physical capacity of students. The obtained data may be applied by physical education instructors, fitness programme trainers, specialists in sports medicine, and organisers of health-promoting activities in higher education institutions to optimise training sessions and to develop effective programmes for improving the physical fitness of young people

Keywords: waist circumference; adipose tissue; cardiovascular system; heart rate; arterial blood pressure; Ruffier-Dixon index; recovery rate

Introduction

The level of physical activity among young people demonstrates a persistent downward trend, which creates preconditions for impaired physical development and the gradual limitation of the body's functional capacities. The period of early adulthood is characterised by substantial changes in the cardiovascular, respiratory, and muscular systems; therefore, an adequate volume of motor activity is a necessary condition for maintaining an optimal functional state. High prevalence of insufficient activity in youth contributes to a decline in aerobic performance, deterioration of morphofunctional indicators, and an increased risk of metabolic disorders. The further progression of these trends is capable of persistently reducing the adaptive capacity of the organism and promoting the early development of chronic functional disorders.

The physical development of young people is determined by the interaction of body composition components, which shape the individual capacity of the organism to respond to aerobic loads. In the study by D. Mohajan & H. Mohajan (2023), it was established that long-term

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regular performance of aerobic exercise contributes to an increase in oxygen consumption, which serves as an integral indicator of cardiorespiratory endurance. The authors demonstrated that improvements in aerobic capacity are driven by adaptive changes in the cardiovascular and respiratory systems and depend on the systematic nature and duration of the training stimulus. The physical status of students as a multidimensional characteristic of the organism was examined in the study by O. Pryimakov *et al.* (2024), which analysed the relationships between indicators of physical condition and the biological age of students in the context of physical education. The researchers found that anthropometric parameters and the level of physical fitness show strong correlations with biological age, allowing these variables to be regarded as informative markers of the organism's adaptive potential and the effectiveness of physical load. In the sample analysed by M. Mendoza-Muñoz *et al.* (2020), a comprehensive assessment of adolescent body composition was conducted, and the influence of the ratio of muscle and fat tissue on physical fitness indicators was determined. The results showed that a higher proportion of fat mass is associated with a reduction in aerobic endurance, whereas a greater muscular component ensures higher work efficiency and a more favourable functional response to physical load. The study by M. Bouamra *et al.* (2022) was aimed at comparing the effectiveness of different training regimes among young people with obesity, assessing changes in body composition, strength, endurance, and components of physical fitness. The obtained data demonstrated that combined programmes (aerobic plus resistance training), in contrast to monotonous training modalities, ensure a more substantial increase in muscle mass, a reduction in the fat component, and a more pronounced improvement in overall morphofunctional status.

The functional capacity of young people reflects the ability of the cardiovascular and respiratory systems to supply the organism with oxygen during prolonged aerobic work. Cardiorespiratory fitness was examined in the study by A.O. Agbaje *et al.* (2021) in conjunction with body composition components and vascular function, in particular, endothelial reactivity, arterial elasticity, and vascular stiffness. The researchers established an association between higher levels of cardiorespiratory endurance, better indicators of vascular function, and lower cardiometabolic risk, which reflects the systemic nature of aerobic adaptation. The responses of the cardiovascular and ventilatory systems were evaluated in the research of F.R. Mendonça *et al.* (2022), which compared the effectiveness of combined aerobic-strength programmes in enhancing the cardiorespiratory resilience of adolescents. The results demonstrated the development of more efficient cardiac and respiratory function, manifested in a lower physiological cost of exercise during standardised tests. In the study conducted by A. Liu (2023), the dynamics of external respiratory function and endurance indicators in students were analysed in response to regular participation in aerobic training. The author demonstrated that adaptation of the respiratory system directly depends on the systematic nature of training stimuli and determines the increase in overall aerobic capacity. The regulatory mechanisms of cardiorespiratory responses were further clarified by A.C. D'Souza *et al.* (2023), who showed that hormonal and neurohumoral factors modulate cardiovascular, respiratory, and metabolic responses to physical exercise, thereby ensuring the stability of functional systems under conditions of aerobic work.

Aerobic programmes in the student population provide a combination of cyclic loading and controlled intensity, creating favourable conditions for the development of positive changes in morphofunctional and psychophysiological indicators. Analysis of the results obtained by A. Chekhovska (2023) confirmed that systematic participation in aerobics leads to an increase in the overall physical fitness of students, particularly through improvements in endurance and motor coordination. It was also emphasised that regular training exposure promotes more stable adaptive responses during physical exertion. The psychophysiological aspects of the effects of aerobics were analysed in the study by N. Chuprun & I. Yurchenko (2020), in which dance-based programmes were applied to assess their effectiveness in restoring regulatory mechanisms and reducing emotional tension. The results confirmed that the impact of aerobic exercise extends beyond motor qualities to the psychoemotional state, ensuring an increase in the functional resilience of students.

Previous studies have not provided a comprehensive analysis of the dynamics of physical development and functional capacity of students in response to structured aerobic programmes. This study aimed to determine the specific features of changes in the morphofunctional indicators of students following the implementation of specially organised aerobics classes. To achieve the stated aim, the following objectives were defined: to record the baseline level of physical development and functional status; to trace the dynamics of the indicators under the influence of the aerobic programme; and to characterise the relationships between morphological and functional parameters.

Materials and Methods

Research setting and sample characteristics

The study involved 40 full-time first- to third-year students of Hryhorii Skovoroda University in Pereiaslav, which served as the base for the experimental research. The mean age of the participants was 19.2 ± 1.1 years, with an age range from 17 to 21 years. This reflected the specific characteristics of the student population and, at the same time, imposed certain limitations on the generalisation of the obtained results to other age categories and social groups beyond the university environment. The gender composition of the sample was uneven: 28 females (70%) and 12 males (30%) participated in the study, which corresponded to the actual structure of physical education groups. For this reason, the results were analysed without division by sex. The experimental phase of the research lasted ten weeks (from 3 February to 13 April 2025) and included the active implementation of the aerobic training programme. During the subsequent two weeks (14-27 April 2025), generalisation, statistical processing, and analytical interpretation of the experimental results were carried out.

The formation of the sample was based on voluntary participation, taking into account predefined inclusion criteria (belonging to the main medical group; absence of acute diseases and decompensated chronic pathologies of the cardiovascular, respiratory, and musculoskeletal systems; regular attendance of physical education classes;

absence of systematic training outside the educational process) and exclusion criteria (the presence of medical contraindications to aerobic exercise; episodes of loss of consciousness or pre-syncope during the previous year; medical recommendations to limit physical activity). During the experiment, three participants withdrew from the study: one due to irregular attendance at training sessions and two due to temporary illnesses. These individuals were not included in the final sample size, and the data obtained from them were not considered in the subsequent analysis of results. The study complied with the guidelines of the European Commission (2021) and was approved by the local ethics committee of the Department of Physical Education of Hryhorii Skovoroda University in Pereiaslav (Protocol No. 1/2025-E dated 31 January 2025). All participants provided written informed consent to participate.

Prior to the start of the experiment, health status screening using a selfassessment questionnaire was conducted among 64 individuals. Based on the screening results and in accordance with the inclusion and exclusion criteria, a proportion of potential participants was excluded from further participation in the study. The questionnaire was developed by the author and consisted of seven questions. It was used as a screening tool to assess the safety of students' participation in the study without quantitative scoring of the results. The questions addressed general well-being, the presence of chronic diseases, possible complaints related to the cardiovascular system, episodes of loss of consciousness, subjective assessment of endurance, the level of additional physical activity, and the presence of medical recommendations to limit physical loads. Responses were provided using a five-point rating scale, "yes/no" options, and gradations of frequency or activity level. In particular, the questionnaire included questions such as: "How do you assess your overall health status?", "Do you have any chronic diseases that may limit physical activity?", and "Do you have any medical recommendations to restrict your level of physical activity?".

Characteristics of the developed training programme

The aerobic training programme was conducted three times per week in the afternoon (approximately from 16:00 to 17:30) under the supervision of a lecturer from the Department of Physical Education, with the participation of the researcher who provided methodological support and monitored compliance of the load with the planned regime. The duration of one session averaged 60-75 minutes (up to 80 minutes at certain stages), and the programme was implemented over a ten-week active phase, which ensured conditions for the development of stable adaptive changes. The preparatory part lasted 10-12 minutes and was aimed at the gradual activation of the cardiovascular and muscular systems. It included light jogging or rhythmic walking (2-3 minutes), a set of joint mobilisation exercises for the cervical, shoulder, elbow, hip, knee, and ankle joints (8-10 repetitions for each movement), as well as dynamic exercises aimed at mobility and stretching. Cones and markers were used to organise movement patterns and spatial orientation, which made it possible to vary movement trajectories and execution tempo.

The main part of the session lasted 40-55 minutes and provided the primary training effect. At the initial stages of the programme, continuous aerobic loads of moderate intensity predominated, including jogging, sequences of aerobic steps, and simple dance combinations accompanied by music. In parallel, bodyweight exercises were performed, such as squats, lunges, jumps, and elements of skipping, which were carried out in sets or in a time-based format (20-40 seconds of work). During this phase, skipping ropes, cones, and exercise mats were actively used. As students adapted to the training load, the structure of the main part was progressively intensified through the inclusion of interval and circuit training formats. Variable running pace was applied, along with interval sets alternating between phases of active work and recovery, as well as circuit complexes consisting of 5-6 exercises (squats, lunges, star jumps, hops, skipping rope exercises, and plank holds). Each exercise was performed for 40-60 seconds with short transition pauses, and a total of 2-3 circuits were completed. Hoops, cones, skipping ropes, and gym mats were used to organise the circuit training. At the final stages of the programme, the main part could take the form of a prolonged continuous aerobic block lasting 35-45 minutes or be combined with an extended circuit training session with variations in work modes. This approach made it possible to increase the overall training volume without a sharp rise in intensity and ensured the development of general aerobic endurance and muscular endurance. The concluding part of the session lasted 8-10 minutes and was aimed at the gradual reduction of functional strain. It included breathing exercises, elements of active relaxation, and static stretching of the main muscle groups, with each position held for 15-20 seconds. Gym mats were used to perform these exercises.

Methods for assessing the morphofunctional status of students

The level of physical development was determined by recording a set of body structure indicators obtained using anthropometric and somatometric methods that characterised the morphological state of the organism. Body height and body mass, waist and hip circumferences, as well as approximate body composition, were measured. Body height was measured using a stationary stadiometer SECA 213 (Germany), and body mass was assessed using Tanita HD-380 electronic scales (Japan) with an accuracy of 0.1 kg. Based on the obtained data, body mass index (BMI) was calculated according to the standard formula:

$$BMI = \frac{m}{h^2}, \tag{1}$$

where m – body mass (kg); h – body height (m); BMI – body mass index (kg/m^2). In addition, indicators of central fat deposition (waist and hip circumferences) were recorded using a Gulik Tape measuring tape (USA) in accordance with the standard protocol: waist circumference was measured at the midpoint between the lower margin of the costal arch and the iliac crest, and hip circumference was measured at the level of the greatest gluteal protrusion. For an approximate assessment of body composition, a domestic bioimpedance analyser OMRON BF511 (Japan) was used, which measured the percentage of body fat, skeletal muscle mass, and phase angle. All anthropometric measurements were conducted by a lecturer from the

Department of Physical Education and the researcher, both of whom had received instruction to standardise measurement techniques.

Testing was performed in the morning (10:00-12:00), prior to training sessions, with participants wearing light sports clothing and no shoes. To improve accuracy, each measurement was recorded twice, and the mean value was calculated; if the difference exceeded 1%, a third control measurement was taken. Baseline testing was conducted before the start of the aerobic programme, and follow-up testing was carried out after the completion of the ten-week training cycle. No intermediate measurement was performed at week five, as morphological indicators change slowly and require a longer period to detect reliable differences. Measurement results were recorded in standardised observation protocols, which included the date of testing, testing conditions, recorded values, and the signature of the person conducting the measurements. Data from the bioimpedance analyser were additionally stored in digital format for subsequent statistical processing.

Functional capacity of the participants was assessed using a battery of tests evaluating aerobic performance, speed-strength and coordination abilities, as well as regulatory responses of the cardiovascular system (CVS). All measurements were conducted in the university sports hall at a fixed time of day (10:00-12:00) under the supervision of a lecturer from the Department of Physical Education and the researcher, who were responsible for organising the tests and ensuring technical control. Resting heart rate (HR), the Ruffier-Dixon index, and blood pressure (BP) were recorded by the university nurse following standard clinical protocols (Muntner *et al.*, 2019; American College of Sports Medicine, 2021).

Aerobic endurance was assessed using the six-minute run test, during which students covered the maximum possible distance over six minutes on a marked circuit. Results were recorded in metres using a CASIO HS-80TW stopwatch (Japan). The test was administered three times: before the start of the programme, after week five, and after week ten. Speed-strength capacity of the lower limbs was evaluated using the standing long jump. Two attempts were performed, and the best result was recorded using a Stanley PowerLock 5 m tape measure (USA). Muscular endurance was assessed by counting the number of correctly performed repetitions (squats or sit-ups) within 30 seconds, with technique monitored via video recording using a Sony HDR-CX405 digital camera (Sony Corporation, Japan). Coordination abilities were evaluated using the 4×9 m shuttle run, with times recorded to 0.1 s using the same stopwatch.

For a more detailed assessment of CVS function, resting HR and blood pressure were measured. Resting, exercise, and recovery heart rates were recorded using a Polar H10 chest heart-rate monitor (Polar Electro Oy, Finland), synchronised with a Polar Vantage M2 watch (Finland), which provided real-time display and recording of data. Maximum HR was calculated using the formula:

$$HR_{max} = 220 - age, \tag{2}$$

where HR_{max} – the estimated maximum heart rate (beats per minute, bpm); *age* – the participant's age in full years. This allowed the determination of the target training zone within 60-75% of HR_{max}:

$$HR_{target} = HR_{max} \times 0.6 - 0.75, \tag{3}$$

where HR_{target} – the target heart rate (bpm) corresponding to the aerobic training zone; HR_{max} – the maximum allowable heart rate; 0.6-0.75 – the intensity range required to ensure predominantly aerobic energy supply. Heart rate recovery after one minute (HRR1) was used as an indicator of cardiovascular functional status and the efficiency of parasympathetic regulation following exercise. A greater reduction in HR during the first minute of rest reflects higher aerobic capacity and the body's ability to recover rapidly. HRR1 was calculated using the formula:

$$HRR1 = HR_{post} - HR_{1min}, \tag{4}$$

where HR_{post} – the heart rate immediately after exercise (bpm); HR_{1min} – the heart rate after one minute of rest (bpm). Blood pressure was measured using an automatic sphygmomanometer, OMRON M3 (Japan), after a five-minute rest, followed by the calculation of pulse pressure:

$$PP = BP_{syst} - BP_{diast}, \tag{5}$$

where BP_{syst} – the systolic blood pressure, representing the maximum pressure in the arteries during heart contraction (mmHg); BP_{diast} – the diastolic blood pressure, reflecting the minimum pressure during myocardial relaxation (mmHg); *PP* – the pulse pressure, the difference between systolic and diastolic pressures (mmHg). CVS function was also assessed using the Ruffier-Dixon index, which involved recording HR at rest, during the first 15 seconds after performing 30 squats in 45 seconds, and after one minute of recovery. The integral index was calculated as:

$$IR = \frac{(P_1 + P_2 + P_3) - 200}{10}, \tag{6}$$

where P_1 – the resting HR (bpm); P_2 – the HR during the first 15 seconds after exercise (bpm); P_3 – the HR during the first 15 seconds of the third minute of recovery (bpm). All functional tests were performed at three observation points: before the start of the programme, at week five, and at week ten. During the training process, exercise intensity was additionally monitored using a Polar Vantage M2 sports watch (Finland), which allowed HR to be maintained within the target aerobic zone and prevented exceeding the optimal load. Results were recorded in standardised protocols signed by the responsible personnel, and data from the heartrate monitor were stored digitally for subsequent statistical analysis.

Assessment standards and statistical processing of results

The interpretation of results was carried out in accordance with international standards for young adults aged 17-21 years, as recommended by the World Health Organization (2020) and the American College of Sports Medicine (2021), as well as physiological studies on heart rate and recovery speed (Vicente-Campos *et al.*, 2014; Hart, 2015; Fryar *et al.*, 2021). BMI values of

18.5-24.9 kg/m^2, waist circumference <94 cm in men and <80 cm in women, and waist-to-hip ratio (WHR) of 0.80-0.90 in men and 0.70-0.80 in women were considered normal, corresponding to a low risk of abdominal obesity (World Health Organization, 2020; Fryar *et al*., 2021). Physiologically normal body fat content was defined as 10-20% in men and 18-28% in women (American College of Sports Medicine, 2021).

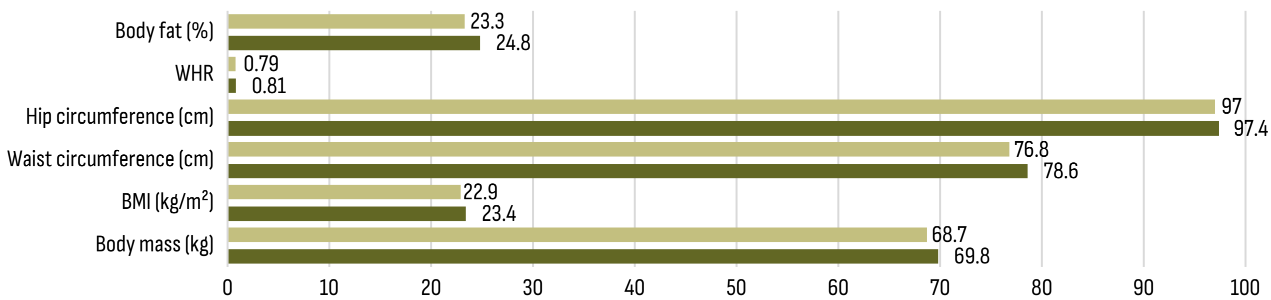
Functional standards stipulated that a resting heart rate of 60-80 bpm in men and 60-85 bpm in women corresponded to normal autonomic regulation (Hart, 2015). Blood pressure within the range 105-125/65-80 mmHg and pulse pressure of 35-50 mmHg were interpreted as indicators of physiological norm for young adults (World Health Organization, 2020). An HRR1 value of 15-24 bpm indicated normal recovery, whereas values above 25 bpm reflected a high level of physical fitness (Vicente-Campos *et al*., 2014). The Ruffier-Dixon index within the range of 0-10 points was interpreted as indicating good or excellent functional status (American College of Sports Medicine, 2021). Assessment of physical fitness was based on generalised predictive norms for young adults: covering 1,100-1,400 m (men) and 900-1,200 m (women) in the six-minute run corresponded to an average or above-average level of aerobic endurance; standing long jump distances of 190-220 cm (men) and 150-180 cm (women) reflected an appropriate level of speed-strength capacity; completing 18-25 repetitions (men) and 15-22 repetitions (women) in 30 seconds indicated normal muscular endurance; and completing the 4×9 m shuttle run in 9.5-10.5 s (men) and 10.5-11.8 s (women) corresponded to age-appropriate coordination abilities (American College of Sports Medicine, 2021; Fryar *et al*., 2021).

Statistical analysis was performed using IBM SPSS Statistics 26.0 software (IBM Corp., USA). Normality of distribution was assessed using the Shapiro-Wilk test. Changes in anthropometric indicators at two time points were analysed using a paired Student's t-test or the Wilcoxon signed-rank test (for non-normal distributions). Functional parameters were evaluated using repeated measures analysis of variance (Repeated Measures ANOVA) or the Friedman test, depending on the distribution characteristics. Correlations between changes in morphological and functional parameters were determined using Spearman's rank correlation coefficient. Data are presented as $M \pm SD$, where M is the mean and SD the standard deviation; statistical significance was set at $p < 0.05$.

Results

Features of morphological adaptation in students to systematic aerobic training

Analysis of morphological changes following a ten-week aerobic programme revealed systematic positive adaptations in students' physical development. These were manifested in reductions in body mass and BMI, decreased abdominal fat accumulation, lower waist circumference and waist-to-hip ratio, and a reduction in body fat percentage. The most pronounced adaptive changes were observed in central fat indicators, reflecting the development of a favourable morphological profile under the influence of regular aerobic exercise. The overall pattern of morphological changes is illustrated in Figure 1, which presents mean values before and after the ten-week programme (BMI was calculated using formula (1)).



	Body mass (kg)	BMI (kg/m^2)	Waist circumference (cm)	Hip circumference (cm)	WHR	Body fat (%)
After programme	68.7	22.9	76.8	97	0.79	23.3
Before programme	69.8	23.4	78.6	97.4	0.81	24.8

Figure 1. Dynamics of morphological indicators before and after the experiment
Source: created by the authors

The dynamics of morphological indicators after the ten-week programme demonstrated the development of coherent positive changes in the structure of students' physical development. The baseline profile of the sample was characterised by normal values for body mass (69.8 ± 7.4 kg), BMI (23.4 ± 2.1 kg/m^2), and waist circumference (78.6 ± 5.8 cm), indicating that the majority of participants did not have excess body weight. This allows the observed changes to be interpreted as adaptive rather than corrective in nature. Following the completion of the programme, body mass decreased to 68.7 ± 7.2 kg, and BMI fell to 22.9 ± 2.0 kg/m^2. Although these absolute changes were modest, they are physiologically consistent with moderate-intensity aerobic training, where fat substrates are primarily utilised while muscle mass is preserved. A reduction in body mass of 1.1 kg and a proportional decrease in BMI of 0.5 kg/m^2 align with the expected rate of fat loss in young adults of this age, without risking the loss of lean tissue.

The most pronounced changes were observed in indicators reflecting central adiposity. Waist circumference decreased from 78.6 ± 5.8 to 76.8 ± 5.5 cm, a mean reduction of 1.8 cm. This change is clinically significant, as abdominal fat exhibits the highest metabolic activity and responds most readily to aerobic exercise. Despite the relatively short intervention period, a near 2 cm reduction in waist circumference indicates activation of lipolytic processes, increased fatty acid oxidation, and improved energy balance. By contrast, hip circumference remained largely stable (97.4 ± 6.2 cm to 97.0 ± 6.1 cm), consistent with typical patterns of morphological adaptation: gluteofemoral fat is more resistant to catabolic processes and changes more slowly than abdominal fat (Snijder *et al*., 2003).

The waist-to-hip ratio, an integral marker of cardiometabolic risk, showed a statistically significant decrease from 0.81 ± 0.04 to 0.79 ± 0.04. This improvement resulted from a greater reduction in waist circumference compared with the hips and indicates a shift in body composition towards lower central fat accumulation. While a WHR decrease of 0.02 units may appear minor in absolute terms, for a young adult sample, it represents a moderate but consistent optimisation of body proportions. Changes were also observed in body fat percentage, as measured by bioelectrical impedance analysis. At the start of the programme, the mean value was 24.8% ± 4.3%, decreasing to 23.3% ± 4.1% by the end. A reduction of 1.5% is considered optimal for a ten-week, moderate-intensity programme (60-75 minutes, three times per week), reflecting enhanced oxidative metabolism and an increased contribution of fat substrates to energy expenditure. Standard deviation remained largely unchanged (4.3 → 4.1), indicating a uniform response to training across the sample without marked individual variability.

Overall analysis of morphological dynamics revealed that waist circumference, WHR, and the fat component were the most responsive indicators to aerobic exercise. These measures capture the early phase of morphological remodelling, characterised by a reduction in central adiposity while preserving muscle mass and maintaining stability in peripheral anthropometric regions. In contrast, body mass and BMI exhibited only modest changes, which is typical for individuals with normal baseline characteristics and confirms that the programme intensity was appropriate without risk of inducing weight deficit. In summary, the ten-week aerobic programme produced a scientifically significant improvement in the morphological status of students, primarily through reductions in central adiposity. This pattern of adaptive changes has preventive significance, as the reduction of abdominal fat is directly associated with a lower cardiometabolic risk and the development of a more favourable somatic profile in young adults.

Changes in cardiovascular functional indicators

The results demonstrated a consistent positive trend across all major functional markers of the cardiovascular system, which was already apparent by the mid-point of the training cycle and became statistically and physiologically significant by the end of the programme. Comparison across the three observation points allowed the characterisation of adaptive changes induced by regular aerobic exercise performed within the target zone of 60-75% of HR_{max}. Final values of the indicators are presented in Table 1. Pulse pressure was calculated using formula 5), HRR1 using formula (4), and the Ruffier-Dixon index using formula (6).

Table 1. Cardiovascular system indicators at three observation points ($M \pm SD$)

Indicator	Before programme	5th week	After programme
Resting HR (bpm)	74.2 ± 6.8	71.1 ± 6.2	69.4 ± 5.9
BP_{syst} (mmHg)	118.2 ± 8.4	116.5 ± 7.9	114.3 ± 7.5
BP_{diast} (mmHg)	74.1 ± 6.1	73.0 ± 5.8	71.6 ± 5.5
Pulse pressure (mmHg)	44.1 ± 4.7	43.5 ± 4.5	42.7 ± 4.3
HRR1, bpm	17.3 ± 3.6	19.8 ± 3.9	22.4 ± 4.1
Ruffier-Dixon index (points)	12.4 ± 3.1	10.2 ± 2.9	8.6 ± 2.7

Source: created by the authors

Resting heart rate demonstrated a gradual decline throughout the observation period. From a baseline of 74.2 ± 6.8 bpm, it decreased to 71.1 ± 6.2 bpm by the fifth week (-3.1 bpm) and to 69.4 ± 5.9 bpm at the end of the programme (-4.8 bpm relative to baseline). This reduction of approximately 6.5% indicates more efficient cardiac function, enhanced vagal control, and reduced sympathetic influence – a characteristic sign of improved aerobic fitness. The rate of decline in resting HR is physiologically appropriate for young adults with normal baseline health status. Blood pressure changes were more gradual but similarly directed. Systolic pressure decreased by 1.7 mmHg by the fifth week and by a total of 3.9 mmHg at the programme's conclusion. Diastolic pressure fell by 1.1 mmHg and 2.5 mmHg, respectively. Such changes, within a 2-4% range, can be interpreted as improvements in arterial tone and reduced peripheral resistance. Importantly, these reductions remained within age-appropriate norms, confirming the safety of the training intervention. Pulse pressure decreased from 44.1 ± 4.7 to 42.7 ± 4.3 mmHg (-1.4 mmHg), indicating enhanced arterial wall elasticity. Since PP is a sensitive indicator of vascular stiffness, its reduction further supports an improvement in the haemodynamic profile.

The most pronounced adaptation was observed in HRR1 – the heart rate recovery during the first minute after exercise. HRR1 increased from 17.3 ± 3.6 to 19.8 ± 3.9 bpm (+2.5 bpm) by the fifth week and to 22.4 ± 4.1 bpm at the final stage (+5.1 bpm relative to baseline, an increase of 29.5%), providing clear evidence of the programme's effectiveness. This change reflects enhanced parasympathetic responsiveness, increased heart rate variability, and accelerated early-phase recovery – key markers of good aerobic fitness. The Ruffier-Dickson index demonstrated an equally significant positive trend. The baseline value was 12.4 ± 3.1 points. By the fifth week, it had decreased to 10.2 ± 2.9 points, a reduction of 2.2 points, or 17.7% of the initial level. By the end of the programme, the index had fallen to

8.6 ± 2.7 points (-3.8 points relative to baseline), representing a 30.6% reduction. This magnitude of change indicates improved cardiac functional response to standardised load, faster recovery processes, and more efficient cardiac function. Post-intervention values below 10 points correspond to a transition to the "good" functional category.

A comprehensive analysis of the data demonstrates that cardiovascular adaptations began by the programme's midpoint and had become systemic and stable by its conclusion. The most sensitive markers were HRR1, resting HR, and the Ruffier-Dickson index – parameters that directly reflect autonomic regulation, recovery efficiency, and aerobic conditioning. Slightly less pronounced, but stable, changes in BP and pulse pressure indicate a gradual improvement in vascular tone and overall haemodynamics. No pathological fluctuations or adverse reactions were recorded at any point, demonstrating the physiological appropriateness and safety of the programme. In summary, the ten-week aerobic intervention produced comprehensive improvements in the regulatory, haemodynamic, and recovery characteristics of the students' cardiovascular system. The observed changes indicate enhanced aerobic capacity, more efficient cardiac function, and strengthened autonomic control. These outcomes have both health-promoting and preventive significance for young people aged 17-21 and confirm the high effectiveness of the proposed programme.

Impact of the aerobic programme on physical fitness and endurance

The analysis of physical fitness indicators at three observation points demonstrated a clear positive trend in adaptive changes resulting from the ten-week aerobic programme. Interim results at the fifth week already showed statistically significant progress in aerobic endurance, speed-strength abilities, muscular endurance, and coordination skills, which continued to develop by the end of the programme. Endurance assessment was conducted within the target training zone, calculated using formulas for maximum heart rate (formula (2)) and training heart rate (formula (3)), providing objective confirmation that the exercise intensity was appropriate. The final and interim results of the physical tests are presented in Table 2, summarising the key transformations in the students' physical fitness profile.

Table 2. Physical fitness indicators at three observation points ($M \pm SD$)

Indicator	Before programme	5th week	After programme
Six-minute run, m	1,162 ± 118	1,234 ± 121	1,316 ± 127
Standing long jump, cm	183.4 ± 16.7	187.2 ± 17.3	191.6 ± 18.1
Muscular endurance (repetitions per 30 s)	21.3 ± 3.9	23.1 ± 4.0	25.4 ± 4.2
Shuttle run 4 × 9 m, s	10.86 ± 0.61	10.52 ± 0.57	10.28 ± 0.54

Source: created by the authors

Analysis of the data in Table 2 indicates that the most pronounced changes were observed in tests reflecting aerobic performance and overall physical fitness. In the six-minute run, the baseline distance was 1,162 ± 118 m. By the fifth week, this increased to 1,234 ± 121 m, demonstrating an early response of the aerobic system even to moderate training loads. After ten weeks, students achieved 1,316 ± 127 m, representing an improvement of 154 m from baseline. This progression reflects increases in stroke volume, mitochondrial density in muscle cells, improved efficiency of peripheral oxygen utilisation, and a reduction in the energy cost of submaximal exercise. Considering that the training sessions were conducted within the target aerobic HR zone, these results indicate that the exercise intensity was sufficient to induce aerobic adaptations and stimulate endurance development.

The standing long jump reflects the speed-strength capacity of the lower limbs, which is traditionally less responsive to aerobic interventions. Nevertheless, the data show a steady increase from 183.4 ± 16.7 cm to 191.6 ± 18.1 cm. The increase of approximately 8 cm can be attributed to the indirect effects of aerobic exercise on the functional state of the lower-limb muscles: regular cyclic movements enhance intermuscular coordination, improve muscular endurance, and optimise motor unit recruitment. The progression in the standing long jump is fully consistent with mechanisms of moderate strength adaptation, which accompany prolonged cyclic activity through increased elasticity of muscle-connective tissue structures and refinement of the technical execution of the movement.

In the muscular endurance test, which measured the number of correctly performed repetitions in 30 seconds, results gradually increased from 21.3 ± 3.9 to 25.4 ± 4.2 repetitions. This improvement indicates enhanced local endurance of the primary muscle groups of the trunk and lower limbs. It is well established that aerobic exercises enhance tissue buffering capacity, facilitate more efficient oxygen utilisation by muscles, and raise the fatigue threshold (McArdle *et al*., 2015). Therefore, changes observed in this test reflect not only an overall improvement in functional resilience but also a systemic reorganisation of energy supply mechanisms towards greater reliance on oxidative processes, even during short-duration strength activities.

The indicator of speed and coordination, assessed using the 4×9 m shuttle run, also showed positive progression. The reduction in completion time from 10.86 ± 0.61 s to 10.28 ± 0.54 s indicates improvements in neuromuscular coordination, acceleration and deceleration capacity, and optimisation of movement skills during frequent changes of direction. Although this test is not directly aerobic, the overall increase in fitness and the reduction in recovery time (as confirmed by the HRR1 dynamics in the previous section) contributed to more efficient performance of the exercise.

In summary, the results indicate that the ten-week aerobic programme produced systemic improvements in the students' physical fitness. The most pronounced gains were observed in aerobic endurance, reflected in a substantial increase in the distance achieved during the six-minute run. Concurrently, the gradual improvements in standing long jump, muscular endurance, and speed-coordination abilities demonstrate the comprehensive nature of the adaptive processes. These changes reflect enhanced oxygen utilisation, strengthening of the functional base of the musculoskeletal system, and improved neuromuscular regulation, collectively confirming the high efficacy of the programme in developing overall physical capacity and functional resilience in young adults.

Correlation analysis of morphological and functional changes

Correlation analysis revealed systematic relationships between morphological changes and functional cardiovascular adaptations induced by the ten-week aerobic training. The findings confirmed that reductions in body fat and optimisation of somatometric proportions have a direct physiological translation into improvements in endurance, recovery, and cardiac efficiency. These results are characteristic of training adaptation processes and allow the effectiveness of the programme to be evaluated not only by the end-point changes but also by the patterns of internal interrelationships. One of the strongest relationships identified in the study was the correlation between reductions in body fat and improvements in HRR1, which reached $r = -0.62$ ($p < 0.01$). The negative direction of the correlation indicates that the greater the decrease in body fat percentage, the larger the increase in HRR1. This aligns with evidence that reduction of the fat component decreases metabolic stress and improves heart rate variability (Brunetto *et al*., 2008). Students exhibiting the most pronounced reductions in body fat (-1.5% to -1.8%) achieved HRR1 values of 23-24 bpm at the end of the programme, substantially higher than the group mean (22.4 ± 4.1 bpm). This relationship demonstrates that changes in the morphological profile have a direct impact on the autonomic regulation of cardiac function. Fat loss enhances baroreceptor sensitivity and accelerates parasympathetic recovery after exercise, explaining the observed increase in HRR1 (Brunetto *et al*., 2008).

A similarly notable relationship was observed between reductions in waist circumference and increases in six-minute run distance ($r = -0.58$; $p < 0.01$). A decrease in waist circumference of 1.5-2.5 cm was accompanied by an increase in distance of 140-180 m, whereas students with less pronounced morphological changes showed gains of only 90-110 m. This relationship has a clear physiological basis: reduction of central adiposity lowers intra-abdominal pressure, improves diaphragmatic mobility, and reduces resistance during respiratory movements (Sonpeayung *et al*., 2020). Reduction of abdominal adipose tissue simultaneously contributes to a decrease in peripheral vascular resistance and an improvement in muscle perfusion through restoration of endothelial function (Aronow, 2017). In practical sports terms, this means that changes in somatic profile alone can serve as a predictor of enhanced aerobic capacity, even when training volume remains constant.

A strong inverse correlation was observed between the Ruffier-Dickson index and six-minute run performance ($r = -0.66$; $p < 0.001$). This indicates that reductions in the index were closely associated with improvements in running distance. Students whose index decreased by more than 3 points increased their run distance by 150 m or more. Since the Ruffier-Dickson index integrates the heart's response to exercise and the speed of recovery, improvement in this measure reflects an increase in stroke volume, economisation of cardiac activity, and enhanced aerobic capacity. Accordingly, the Ruffier-Dickson index proved to be a sensitive marker of training adaptation, capable of signalling functional progress even before changes in body mass or circumferences became evident.

A moderate but statistically significant correlation was identified between BMI and muscular endurance ($r = -0.41$; $p < 0.05$). Students who reduced their BMI by 0.3-0.6 kg/m^2 exhibited greater increases in repetitions during the 30-second test (up to +5-7 repetitions). Physiologically, this can be attributed to a reduction in mechanical load on the musculoskeletal system and an improvement in the muscles' functional capacity to perform cyclic local efforts under conditions of reduced metabolic stress. This confirms that even a modest optimisation of body mass and height parameters can enhance overall physical capacity.

A cumulative analysis demonstrated that the strongest correlations were observed in measures sensitive to central adiposity – waist circumference, fat mass, and WHR. This underscores a fundamental principle of exercise physiology: central obesity is a key modifier of functional status and determines cardiovascular efficiency during aerobic exercise. The identified correlations indicate that morphological changes do not merely accompany training adaptations but actively shape them. Reduction of fat mass, particularly abdominal fat, is a determinant of increased endurance and accelerated recovery responses. In summary, the correlational analysis confirmed that the ten-week aerobic programme elicited coordinated improvements in both morphological and functional characteristics, with HRR1, the Ruffier-Dickson index, and six-minute run performance serving as the primary integrative markers of effectiveness. These relationships highlight the practical significance of optimising body composition as a prerequisite for enhancing aerobic performance and functional resilience in university students.

Discussion

The results demonstrate that the ten-week aerobic programme produced comprehensive positive changes in students' morphological and functional indicators. Moderate reductions were observed in body mass, BMI, waist circumference, and fat component, while peripheral anthropometric zones remained stable, indicating an early phase of central fat reduction. Cardiovascular parameters also improved: resting HR and blood pressure decreased, while HRR1 and the Ruffier-Dickson index reflected accelerated recovery processes. Simultaneously, aerobic endurance, muscular endurance, and coordination improved, confirming the systemic training effect of the programme.

Changes in morphological indicators following the ten-week programme were moderate but statistically significant: body mass decreased from 69.8 ± 7.4 to 68.7 ± 7.2 kg, BMI from 23.4 ± 2.1 to 22.9 ± 2.0 kg/m^2, waist circumference from 78.6 ± 5.8 to 76.8 ± 5.5 cm, and body fat percentage from 24.8% ± 4.3% to 23.3% ± 4.1%. This pattern of morphological change is consistent with the findings of C. Lan *et al*. (2022), who reported that regular aerobic programmes in a student cohort contributed to reductions in body mass, BMI, and fat component, particularly in measures of central adiposity. The authors highlighted that waist circumference is a sensitive marker of adaptation to systematic aerobic training, aligning with the dynamics observed in the present study. These trends also correspond with the conclusions of M.B. Batista *et al.* (2020), which indicated that body mass status and the degree of biological maturation determine aerobic capacity in young males. The authors found that BMI reduction is a typical response to moderate-intensity training in young individuals with an established somatic profile, reflecting the BMI dynamics observed in the 17-21-year-old cohort of the current study.

Similar findings have been reported by B.S. Chauhan & S. Kumar (2023), who evaluated the effects of regular aerobic exercise on the morphological characteristics of undergraduate students and found that systematic training produced a moderate reduction in body mass and BMI within the young adult cohort. These results are further corroborated by Y. Soylu *et al.* (2023), who examined the effectiveness of two self-regulated aerobic training regimes in physically active young adults. Their study demonstrated that both regimes led to moderate decreases in body mass and fat tissue, consistent with the magnitude of morphological changes observed following the ten-week programme in the student cohort. By contrast, the changes observed in the present study were less pronounced than those reported by D. Djordjevic *et al.* (2021), who investigated the effects of aerobic exercise on body composition in children and adolescents. That study documented greater reductions in fat mass and faster morphological adaptation. The partial discrepancy can be attributed to age-related differences, as younger individuals exhibit greater metabolic plasticity and a more rapid response of adipose tissue to cyclical exercise.

The indicators of the cardiovascular system demonstrated a distinct positive trajectory: resting heart rate decreased from 74.2 ± 6.8 to 69.4 ± 5.9 bpm, systolic arterial pressure from 118.2 ± 8.4 to 114.3 ± 7.5 mmHg, and diastolic pressure from 74.1 ± 6.1 to 71.6 ± 5.5 mmHg. Notably, the HRR1 metric increased from 17.3 ± 3.6 to 22.4 ± 4.1 bpm. The Ruffier-Dixon index decreased from 12.4 ± 3.1 to 8.6 ± 2.7 points, indicating an improved cardiac response to standardised exercise. The observed changes in resting HR, HRR1, and the Ruffier-Dixon index align with the findings of J.M. Thomas *et al.* (2022), who highlighted the utility of HRR as a marker of cardiorespiratory fitness and the efficiency of autonomic cardiovascular regulation in young adults. The consistency in adaptive trends suggests that systematic moderate-intensity aerobic exercise enhances parasympathetic control of cardiac activity and optimises recovery processes following physical exertion. Similar patterns were reported by N. Armstrong & J. Welsman (2020), where regular cyclic exercise in young adults led to a gradual reduction in resting HR and improved cardiac reactivity to physical load. The agreement between these studies indicates that even relatively short interventions can initiate the early phase of cardiorespiratory adaptation.

The dynamics of HRR1 corresponded with trends observed by G. NavarroLomas *et al.* (2022), in which various training modalities in young adults increased heart rate variability and accelerated parasympathetic recovery. This similarity underscores the role of aerobic training in establishing a more economical and controlled heart rhythm. Improvements in the Ruffier-Dixon index are also consistent with the conclusions of H.C.D. Souza *et al.* (2021), who demonstrated that enhanced cardiorespiratory fitness in young adults is accompanied by strengthened autonomic regulation and more efficient recovery following standardised exercise. The results partially align with those reported by R. Sloan *et al.* (2021), who observed more pronounced improvements in haemodynamic parameters and responses to orthostatic and psychological stimuli following aerobic training. The smaller magnitude of adaptive changes in the present study is likely due to the shorter programme duration and differences in the participants' baseline functional status.

The findings demonstrated a gradual enhancement of students' physical fitness over the ten-week aerobic programme: the six-minute run distance increased from $1{,}162 \pm 118$ m to $1{,}316 \pm 127$ m; the standing long jump improved from 183.4 ± 16.7 cm to 191.6 ± 18.1 cm; muscular endurance rose from 21.3 ± 3.9 to 25.4 ± 4.2 repetitions; and the 4×9 m shuttle run time decreased from 10.86 ± 0.61 s to 10.28 ± 0.54 s, indicating gains in endurance, strength, and coordination. Similar patterns were reported by C. Lourenço *et al.* (2025), who identified a relationship between weekly physical activity volume and students' fitness indicators, particularly endurance and strength. Comparable trends were also noted by M. Saputra *et al.* (2024), where comparisons of different forms of aerobic activity revealed improvements in overall physical performance and muscular endurance, consistent with the dynamics observed in the present sample.

In the study by A. Agus & F. Mukhtarsyah (2021), the effects of aerobic exercise on students' physical fitness were examined, showing that systematic aerobic training led to improvements in motor performance, particularly endurance, speed-strength characteristics, and coordination skills. These findings align with the observed changes in standing long jump performance and shuttle run times in the present sample. Data from B. Rogers *et al.* (2021) demonstrated that training intensity guided by heart rate variability reliably enhances aerobic performance. The increases in six-minute run distance and muscular endurance observed in this study are consistent with this trend. The overall improvement in endurance, strength, and coordination among students following the ten-week programme corresponds with the results reported by X. Yu (2025), where an aerobic dance intervention in university students simultaneously enhanced cardiorespiratory endurance, muscular qualities, and motor preparedness.

Correlation analysis revealed clear relationships between morphological and functional changes in the students. Reductions in fat mass were associated with increases in HRR1 ($r = -0.62$; $p < 0.01$), decreases in waist circumference correlated with gains in six-minute run distance ($r = -0.58$; $p < 0.01$), reductions in the Ruffier-Dickson index corresponded with improvements in aerobic endurance ($r = -0.66$; $p < 0.001$), and decreases in BMI were linked to increases in muscular endurance ($r = -0.41$; $p < 0.05$). A similar interrelationship between parameters is supported by the study of N.E. Wade *et al.* (2020), which examined associations between aerobic fitness and brain morphometric characteristics in young adults. The authors demonstrated that superior physical fitness is linked to more efficient neurofunctional organisation, consistent with the observed association in the present sample between HRR1 and changes in the morphological profile. Results from D. Mongin *et al.* (2022) indicated that reductions in heart rate variability during exercise serve as a highly sensitive indicator of cardiorespiratory fitness. This mechanism aligns with the detected correlation between HRR1 and fat mass, as both indices reflect the efficiency of autonomic regulation.

In the study by J.A. Pérez-Ramírez *et al.* (2025), high-intensity interval programmes in schools led to improvements in adolescents' endurance and physical fitness. The association observed in the current sample between waist circumference and running distance corroborates the conclusion that changes in morphological profile directly influence aerobic performance. Similarly, T.G. Nguyen & O. Gomez (2024), in their research on models of aerobic control and the design principles of effective fitness systems, demonstrated that optimisation of morphological parameters – particularly the ratio of muscle to fat tissue – is a key mechanism for enhancing aerobic capacity. This finding aligns with the correlation observed in the student sample between reductions in BMI and gains in muscular endurance. The study by G.M.G. Bonuzzi *et al.* (2020), which examined the effects of aerobic exercise on the acquisition of complex motor skills, demonstrated that improvements in motor control are accompanied by functional changes in cardiorespiratory systems. A similar pattern was observed in the present study, where the Ruffier-Dickson index was closely associated with performance in the six-minute run.

In summary, the results of the study demonstrated consistent positive changes in students' morphological, functional, and physical indicators, aligning with the evidence reported in numerous scientific studies that confirm the effectiveness of structured aerobic interventions for young adult populations. The direction of adaptive responses – including reductions in fat mass, improvements in cardiovascular regulation, and increases in endurance and motor abilities – replicates findings from research conducted across various age groups and training contexts, underscoring the consistency of the observed effects with general patterns of aerobic adaptation.

Conclusions

The developed aerobic programme resulted in targeted improvements in students' morphological profiles: body mass decreased by 1.1 kg, BMI by 0.5 kg/m^2, waist circumference by 1.8 cm, and body fat percentage by 1.5%. The most pronounced changes in waist circumference and fat mass indicate a reduction in central obesity – a key factor in cardiometabolic risk. This pattern of adaptation reflects the activation of lipolysis and a restructuring of energy metabolism without loss of muscle mass, which is a typical effect of regular aerobic exercise. The functional status of the cardiovascular system also improved: resting HR decreased by 4.8 bpm, systolic and diastolic blood pressure fell by 3.9 mmHg and 2.5 mmHg, respectively, and pulse pressure decreased by 1.4 mmHg. The HRR1 index increased by 5.1 bpm, while the Ruffier-Dickson index decreased by 3.8 points, indicating a substantial enhancement of parasympathetic control, improved cardiac efficiency, and more effective recovery processes. All observed changes are consistent with typical mechanisms of aerobic adaptation in young adults.

Physical fitness indicators improved across all tests: the six-minute run distance increased by 154 m, muscular endurance by 4.1 repetitions, standing long jump by 8.2 cm, and the 4×9 m shuttle run time decreased by 0.58 s. This pattern demonstrates gains in aerobic capacity, muscular endurance, speed-strength characteristics, and coordination, highlighting the effectiveness of the programme in developing multi-component motor fitness. Correlation analysis confirmed the interdependence of morphological and functional adaptations: reductions in fat mass were associated with increases in HRR1 (r = -0.62), decreases in waist circumference with improvements in six-minute run distance (r = -0.58), decreases in the Ruffier-Dickson index with enhanced running performance (r = -0.66), and reductions in BMI with gains in muscular endurance (r = -0.41). These findings indicate that morphological optimisation serves as a key determinant of functional progress, particularly in cardiovascular regulation and physical performance. Recommendations for future research include expanding sample sizes across age groups and involving multiple educational institutions to increase representativeness and enable comparative analyses.

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Conflict of Interest

None.

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Динаміка фізичного розвитку та функціональних можливостей організму молоді 17-20 років під впливом аеробіки

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Анотація. Мета роботи – виявити особливості змін показників фізичного розвитку та функціональних можливостей молоді у результаті застосування розробленої аеробної програми. Дослідження проводилось на базі Переяславського університету імені Григорія Сковороди (Київська область) упродовж десяти тижнів (3 лютого – 13 квітня 2025 р.) із залученням 40 студентів віком 17-21 років. Експериментальне дослідження включало три етапи вимірювань, що дозволило оцінити динаміку морфологічних і функціональних показників у студентів під впливом структурованої аеробної програми. Результати дослідження засвідчили, що маса тіла зменшилася на 1,1 кг, індекс маси тіла – на 0,5 кг/м^2, окружність талії – на 1,8 см, а частка жирової тканини – на 1,5 %, що відображало редукцію центрального жиру та оптимізацію соматичного профілю. Показники серцево-судинної регуляції також покращилися: частота серцевих скорочень у спокої знизилася на 4,8 уд/хв, систолічний тиск – на 3,9 мм рт. ст., діастолічний – на 2,5 мм рт. ст., а швидкість відновлення частоти серцевих скорочень зросла на 5,1 уд/хв. Індекс Руф'є-Діксона зменшився на 3,8 бала, що свідчило про підвищення реактивності та відновних можливостей. Показники фізичної підготовленості демонстрували зростання: дистанція шестихвилинного бігу збільшилася на 154 м, стрибок у довжину – на 8,2 см, м'язова витривалість – на 4,1 повторення, а час човникового бігу 4×9 м покращився на 0,58 с. Сукупність отриманих змін підтверджує ефективність аеробної програми як засобу розвитку загальної фізичної дієздатності студентів. Отримані дані можуть бути використані викладачами фізичного виховання, тренерами фітнес-програм, фахівцями спортивної медицини та організаторами оздоровчих заходів у закладах вищої освіти для оптимізації навчально-тренувальних занять і розроблення ефективних програм фізичної підготовленості молоді

Ключові слова: окружність талії; жирова тканина; серцево-судинна система; частота серцевих скорочень; артеріальний тиск; індекс Руф'є-Діксона; швидкість відновлення