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Aerobic exercise as a factor of adaptive changes in the physical and functional states of adolescent girls

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Abstract. The purpose of the study was to comprehensively characterise changes in indicators of physical fitness and functional capabilities of adolescent girls depending on the level of motor activity under the influence of aerobic loads. The study was conducted at the Pereyaslav Gymnasium No. 3 (Kyiv Oblast) during March 17 – May 25, 2025 and included an aerobic programme with two stages of measurement, which allowed analysing the dynamics of physical fitness and functional indicators of the cardiovascular system of adolescent girls with different levels of motor activity. It was found that in the high-activity group, the distance of six-minute running increased from 900 ± 100 m to 1,130 ± 90 m (+25.6%), while in the low-activity group – from 820 ± 95 m to 950 ± 85 m (+15.9%). The number of squats in 30 seconds increased by +45% (from 20 ± 4 to 29 ± 3) against +33.3% (from 18 ± 4 to 24 ± 3). The 4×9 m shuttle run performance improved moderately: -1.1 s in high-activity and -0.7 s in low-activity. Functional changes in the cardiovascular system were manifested by a decrease in the resting heart rate by -11.4% and -7.3%, respectively, an increase in recovery in the first minute by +54.5% against +44.4%, and a decrease in the Ruffier-Dixon Index by 29.7% and 21.6%, which reflects an improvement in the functional state. Correlation analysis confirmed that the level of motor activity was statistically associated with the scale of adaptive changes ($r = 0.68$-0.72; $p < 0.01$). Thus, the initial motor status determined the training sensitivity of adolescent girls and influenced the nature of changes in physical fitness and functional indicators. The obtained data can be used by physical education teachers, trainers, and specialists of health programmes to differentiate the load, taking into consideration the initial level of motor activity of girls

Keywords: motor activity; training effect; muscle endurance; recovery rate; cardiovascular system; girls aged 13-15; fitness programmes

Introduction

Aerobic exercise is a determining factor in the physiological changes in adolescent girls, since during this period an intensive development of the cardiovascular and respiratory systems and the physical performance takes place. According to the World Health Organization (n.d.), approximately 81% of teens aged 11-17 do not follow the recommendation of 60 minutes of moderate-to-high-intensity physical activity each day. Moreover, girls show a lower level of motor activity: only a small proportion of them meet the established recommendations, while the majority (about

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85%) do not reach the required standards. For boys, this indicator is slightly better and amounts to approximately 78%, which indicates a higher probability of insufficient physical activity among teenage girls. This trend leads to a decrease in aerobic performance, disruption of adaptation mechanisms, an increased risk of obesity, metabolic disorders, dysfunction cardiovascular system (CVS), and early development of chronic non-communicable diseases in later life. As a result, this leads to reduced functionality, poor quality of life, and an increased likelihood of medical complications.

Analysis of the influence of aerobic exercise on the physical fitness and morphological characteristics of adolescent girls allows outlining the most effective approaches to planning physical activity during extracurricular activities. The finding of O. Brezdeniuk *et al.* (2021) demonstrated that as a result of performing a combined aerobic-anaerobic programme, adolescents with different body weight components showed a decrease in body fat and an improvement in the somatic profile. The researchers have found that several weeks of systematic performance of training sessions provides an increase in endurance, which is considered as a formed adaptive response to the training impact. In programmes for girls aged 12-13 years, the use of structured wellness classes with an aerobic focus provided an increase in strength endurance and coordination abilities, which is reflected in the findings of Y. Galan *et al.* (2020). In the same study, early positive dynamics of morphofunctional indicators were found after several weeks of systematic exposure, which indicates a high training sensitivity in this age group. The correlation analysis described by I. Ivanyshyn *et al.* (2021) confirmed a close relationship between the level of aerobic performance and integral physical condition, which allows interpreting this indicator as a key indicator of adaptation. Variable aerobic fitness programmes contribute to an increase in functional capabilities and improvement in cardiovascular system indicators, as reported by V. Sliusarchuk *et al.* (2023). Researchers have also substantiated the effectiveness of comprehensive training through confirmed quantitative changes in endurance and cardiopulmonary parameters, which reinforces the importance of combining different aerobic components. The integration of fitness modules into the structure of physical training sessions leads to a steady improvement in the level of physical endurance, which was confirmed in the study by M. Chekhovska *et al.* (2020), where an increase in girls' involvement in motor activity was recorded.

Cardiorespiratory adaptations under the influence of aerobic training programmes in adolescents are characterised by a gradual improvement in the mechanisms of oxygen delivery and utilisation, which determines the level of endurance and load tolerance. In the long-term follow-up described in paper by T. Ingvarsdottir *et al.* (2024), a stable increase in maximum oxygen consumption was recorded in adolescent girls, accompanied by an improvement in cardiorespiratory efficiency. The researchers emphasised the importance of the duration of exposure for the development of persistent adaptive changes. The variability of the response to training loads depending on biological age and the level of athletic fitness was reflected by J.R. Padilla-Alvarado *et al.* (2025), who showed different aerobic power profiles in girls of different age groups. The researchers established a relationship between the rate of adaptation and the correspondence of training impact to individual capabilities. The school curriculum analysed by J. Wan *et al.* (2025) indicated an increase in physical fitness and cardiorespiratory parameters under controlled conditions. The high effectiveness of this programme was confirmed by the structure of the impact and the regularity of performing exercises.

Physiological mechanisms of adaptation to aerobic exercise in adolescent girls are determined by structural, hormonal, and metabolic changes that affect the effectiveness of the training response. The study by M.I. Forså *et al.* (2023) found the remodelling of cardiac structures under the influence of systematic training, which is characterised by an increase in stroke volume and improved pumping function. The researchers noted gender differences in cardiac adaptations that shape different developmental trajectories. Features of cardiorespiratory response and changes in exercise tolerance at different phases of the menstrual cycle were described by B. Rael *et al.* (2021), who recorded fluctuations in performance indicators depending on the hormonal background. It is these changes that determine the individual variability of adaptation to training. According to H.N. Willett *et al.* (2021), during aerobic exercise there is a shift in substrate use towards oxidative processes, which provides more efficient energy support for muscle work, and insufficient level of motor activity in girls forms the risk of metabolic shifts and reduced adaptive capabilities.

Despite the available scientific studies, the features of the development of adaptive changes in adolescent girls in conditions of different levels of motor activity under the influence of aerobic loads are not sufficiently covered. The purpose of the study was a comprehensive description of changes in indicators of physical fitness and functional capabilities of adolescent girls depending on the level of motor activity under the influence of aerobic loads.

Materials and Methods

The study involved female students ($N = 30$) aged 13-15 years from grades 7-9 of Pereyaslav Gymnasium No. 3 (Pereyaslav, Kyiv Region) who had no medical restrictions on performing aerobic exercises and regularly attended physical education classes. Students were excluded at the initial assessment stage if any restrictions on the cardiovascular, respiratory, or musculoskeletal systems were detected, or if there were factors that prevented stable attendance or significantly changed their usual motor activity (for example, participation in specialised sports sections). Parents and students received written information about the purpose, content, and potential physical exertion, and then confirmed their consent to the children's participation. All procedures were in accordance with the European Commission (2021) guidelines on ethics and processing of personal data. During the study, no medical interventions were used, and the information obtained was stored in an anonymous form in compliance with the requirements for preventing the disclosure of private information. The study lasted for two and a half months of the spring semester of 2025 (from March 15 to May 25, 2025).

Statistical processing was based on a consistent assessment of the properties of sample data, primarily their compliance with the normal distribution, which was tested using the Shapiro-Wilk criterion. After determining the type of distribution, a further analysis method was chosen: if parametric assumptions were met, the dynamics of changes were considered using repeated measurement analysis models of variance (ANOVA), while the nonparametric Friedman criterion was used for their violation with subsequent paired comparisons. Comparisons between the two independent groups were performed using the t-test or the corresponding non-parametric Mann-Whitney test. Spearman correlation analysis was used to assess the associations between the level of motor activity and the magnitude of adaptive changes. All calculations were performed in IBM SPSS Statistics 29.0 and Microsoft Excel 2021 Microsoft Excel 2019 environments.

Participants were divided according to their level of motor activity, as a result of which two comparison groups were formed: girls with a lower level of activity ($n = 17$) and girls with higher activity indicators ($n = 13$). To determine the individual level of activity, a version of the Physical Activity Questionnaire for Adolescents (PAQ-A) adapted to the school environment was used. During the adaptation, the wording of the questions was clarified and examples of typical activities were given, without changing the structure of the tool, the rating scale, and the algorithm for calculating the total score (Table 1).

Table 1. Questionnaire for determining the level of motor activity (modified version of PAQ-a)

No.	Question	Answer options (points)
1	How many times in the last 7 days have you done physical exercises or sports outside of physical education classes lasting ≥ 20 minutes?	1 – never; 2 – 1 time; 3 – 2-3 times; 4 – 4-5 times; 5 – ≥ 6 times
2	How often have you participated in outdoor games or active leisure activities (running, jumping, cycling, dancing, etc.)?	1 – never; 2 – rarely; 3 – sometimes; 4 – often; 5 – very often
3	What was your activity in physical education classes?	1 – almost did not participate; 2 – low; 3 – medium; 4 – active; 5 – very active
4	How much time did you spend sitting after school (phone, computer, TV)?	1 – ≥ 5 hours/day; 2 – 4 hours; 3 – 3 hours; 4 – 2 hours; 5 – ≤ 1 hour
5	How often have you attended sports clubs or clubs in the last 7 days?	1 – did not visit; 2 – 1 time; 3 – 2 times; 4 – 3-4 times; 5 – ≥ 5 times
6	How often were you physically active on weekends?	1 – not active at all; 2 – little active; 3 – medium active; 4 – active; 5 – very active
7	How do you rate your overall physical activity over the past week?	1 – very low; 2 – low; 3 – medium; 4 – high; 5 – very high

Source: adapted by the authors based on the original PAQ-A questionnaire by K.C. Kowalski *et al.* (2004)

For each participant, the average total score was calculated as the average value of responses to seven questionnaire questions. Based on the obtained scores, the level of motor activity was stratified by dichotomising PAQ-A indicators: girls with a total score <2.5 were assigned to the group with a lower level of activity, while participants with indicators ≥2.5 were assigned to the group with a higher level of activity. The applied threshold level was determined based on the median value of the obtained data, which helped to avoid artificially isolating the conditional "average" level of activity. Classes were conducted by a physical education teacher with the participation of the author of the study, who provided methodological support and monitoring of exercise performance. Training sessions were held three times a week (Monday, Wednesday, Friday) after school from 15:30 to 16:30 and lasted 50-60 minutes. The structure of classes provided for a warm-up, the main aerobic block, and the final part with a gradual increase in the duration of the active part of the lesson, which provided a gradual increase in the training load in accordance with the adaptive capabilities of the participants and contributed to the development of stable functional changes without the risk of overexertion (Table 2).

Table 2. Structure of the aerobic training programme

Duration	Content / exercises	Equipment
Warm-up		
10 min	Light running 2 min; joint exercises 5 min (movements in the neck, shoulder, elbow, knee, and ankle joints, 8-10 repetitions); dynamic stretching 3 min	Cones, markers
Main block		
30 min (weeks 1-2)	Jogging for 6-8 minutes; relay run with turns; jumps "star" 3×20 repetitions; jumps in place 3×30 s; general physical training complexes (squats 2×12, lunges 2×10 on the leg, "skipping" 2×30 s)	Cones, jump ropes
35 min (weeks 3-4)	Variable pace running 10 min (1 min faster / 1 min slower); jumping series 3×40 s; bodyweight exercises: squats 3×12, lunges 3×10, "skipping" 3×30 s, "plank" 2×30 s	Cones, mats
40 min (weeks 5-7)	Interval running 2 minutes of running / 1 minute of walking × 6 cycles; circular complexes of general physical training: 6 exercises were performed sequentially for 40 seconds out of 20 seconds of transition (squats, jumps "star", lunges, "plank", jumps, "skipping"), 2 sets	Cones, hoops, jump ropes, mats
40 min (weeks 8-10)	Training session consisting of 6 exercise sets: 1) running between cones; 2) jumping "star"; 3) squats; 4) lunges; 5) skipping rope; 6) jumps; performing 45 seconds with 15 seconds of transition, 2-3 sets or a long continuous run of 35-40 minutes	Cones, jump ropes
Final part		
10 min	Breathing exercises 3 min; static stretching of the main muscle groups 7 min (holding 15-20 s)	Floor mats

Source: developed by the authors

If necessary, individual adjustments were made to the pace and volume of exercises performed for participants with a lower level of physical fitness, which was implemented through a temporary reduction in the duration of working intervals or an increase in rest pauses without changing the overall structure of the lesson. The menstrual cycle was considered as a potential factor affecting performance and well-being: before each training session and testing, a short survey was conducted regarding the presence of menstrual symptoms, and according to their severity, the intensity of the load was adjusted in a similar way. The test measurements were not postponed, but the protocols were marked relative to the cycle phase, which provided a more correct interpretation of the results obtained.

The level of physical fitness was assessed based on the results of standardised tests used in the school system of physical education and recommended for the adolescent contingent. The six-minute run was used to determine aerobic endurance and involved overcoming the maximum distance in 6 minutes on a marked 200-metre circle in the gym or on the school playground (the result was recorded in metres). The long jump from a standstill allowed assessing the speed and power abilities of the lower extremities, the performance was carried out from the starting position on the start line with a push-off with both feet, and the result was measured in centimetres from the push-off line to the nearest point of contact with the surface. 30-second squats were used to assess muscle endurance and included the maximum number of correct repetitions in a given time with control of the execution technique. The 4×9 m shuttle run evaluated coordination abilities and agility and included four movements between markers at a distance of 9 meters with a record of total execution time. Functional status was determined by resting and post-exercise heart rate (HR), recovery rate, and the Ruffier-Dixon Index, which allowed assessing aerobic performance and CVS response to a physical stimulus. The maximum heart rate was calculated using the generally accepted formula:

$$HR_{max} = 220 - age, \qquad (1)$$

where HR_{max} – estimated maximum heart rate (bpm); *age* – participant's age in full years. The target training area was determined in the range of 60-75% of HR_{max}:

$$HR_{tr} = HR_{max} \times 0.60 - 0.75, \qquad (2)$$

where HR_{tr} – target training heart rate (bpm) corresponding to the aerobic exercise zone; HR_{max} – maximum allowable heart rate; 0.60-0.75 – range of load intensity that ensures the aerobic nature of energy supply. The Ruffier-Dixon Index was used to determine the integral CVS response to exercise and recovery efficiency. The assessment was performed by a nurse by measuring heart rate by palpation of the radial artery on the wrist of the non-dominant hand for 15 seconds in a sitting position, repeated measurement immediately after performing 30 squats for 45 seconds, and after one minute of recovery. The index was calculated using the equation:

$$IR = \frac{(P_1+P_2+P_3)-200}{10}, \qquad (3)$$

where P_1 – resting HR (bpm); P_2 – HR in the first 15 seconds after exercise (bpm); P_3 – HR in the first 15 seconds of the third minute of recovery (bpm). The effectiveness of recovery processes was further characterised by the difference between heart rate immediately after exercise and after one minute of rest (HRR1), calculated based on sample data.

Results

Dynamics of physical fitness in girls with different levels of motor activity

The obtained data helped to outline the specifics of the course of adaptive shifts in the indicators of physical fitness of adolescent girls under the influence of an aerobic training programme and determine the role of the initial level of motor activity in the development of a training response. Comparison of these measurement steps allowed tracking the sequence and rate of changes and assessing intergroup differences, which was important for confirming the assumption of a differentiated body response to the same training stimulus. The summary results of physical fitness indicators are shown in Table 3, which provides a holistic view of the dynamics of endurance, speed, strength, and coordination abilities in the study groups.

Table 3. Changes in girls' physical fitness indicators ($M \pm SD$)

Indicator	Measurement period	Low activity level ($n=17$)	High activity level ($n=13$)
6-min run, m	Beginning	820 ± 95	900 ± 100
	End	950 ± 85	1,130 ± 90
Long jump, cm	Beginning	145 ± 12	150 ± 13
	End	156 ± 11	168 ± 12
Number of squats in 30 s	Beginning	18 ± 4	20 ± 4
	End	24 ± 3	29 ± 3
Shuttle run 4×9 m, s	Beginning	12.8 ± 0.7	12.5 ± 0.6
	End	12.1 ± 0.5	11.4 ± 0.4

Source: compiled by the authors

A comprehensive analysis of the table data showed that the greatest dynamics of changes can be traced in the results of 6-minute running, which is an integral test of aerobic endurance and the effectiveness of the cardiorespiratory system. In the high-activity group, the distance increased from 900 ± 100 m to 1,130 ± 90 m, which was almost 25.6% increase, while in the low-activity group, the increase was about 15.9 % (from 820 ± 95 m to 950 ± 85 m). This difference indicated that the body of girls with a higher initial level of activity already had formed mechanisms of oxygen supply to the muscles, in particular, a larger stroke volume of the heart, more efficient peripheral blood circulation, and a better ability to use oxygen in tissues. In the low-activity group, positive changes reflected the initial phase of training adaptation, which is usually characterised by an increase in ventilation efficiency and an improvement in movement economisation. The long jump from a standstill showed an increase in speed and strength capabilities, but the growth rate also depended on the initial motor status. An 11 cm increase in the result in the low-activity group indicated improved coordination between lower limb muscle groups and increased strength response. In the high-activity group, the increase reached 18 cm, which indicated more effective neuromuscular control, faster involvement of motor units, and an optimal level of intermuscular coordination. Such changes are typical for the first stage of adaptation, when the training effect is manifested mainly due to neuromotor mechanisms, and not structural changes in muscle tissue, as evidenced by previous scientific data (Gillen *et al*., 2019).

Squat scores for 30 seconds reflected the development of muscle endurance in the lower extremities. Participants with high activity showed an increase in the number of repetitions from 20 ± 4 to 29 ± 3 (+45%), which indicated an increase in the ability to perform long-term repetitive work. In the low-activity group, the increase was from 18 ± 4 to 24 ± 3 (+33.3%), which was also an indicator of positive changes, but less intense. This is conditioned by the different efficiency of aerobic energy resynthesis, the rate of metabolite elimination, and local muscle endurance. According to available scientific evidence, girls with higher motor activity may have a higher proportion of type 1 oxidative muscle fibres and higher capillarisation, which potentially ensures more efficient use of oxygen and faster recovery during repeated loads (Shadiow *et al*., 2023). The smallest changes were recorded in the 4×9 m shuttle run, which is a test of coordination abilities and agility. An improvement of 0.7 s in the low-activity group (reduced time by -5.5%) and 1.1 s in the high-activity group (reduced by -8.8%) indicated a certain increase in the speed of movement and the effectiveness of changing the direction of movement, but the training programme was not aimed at specific development of coordination. This explains the limited training effect, since coordination abilities require exercises with complex motor structures, variable trajectory, and sensorimotor loads, which the programme practically did not contain.

Overall, the results showed that the aerobic programme provided the initial training adaptations, most pronounced in the development of aerobic and muscular endurance. It was found that a higher level of initial activity determines a greater adaptive reserve, faster growth rates, and more effective implementation of physiological mechanisms. This trend is consistent with the position that the training effect depends on the initial functional status, according to which the body with a higher level of fitness reacts more powerfully due to optimised metabolic and neuromuscular processes. Thus, the data obtained confirmed that the level of motor activity was a determining factor in the adaptive response to aerobic exercise in adolescence, and systematic training sessions became an effective means of improving the physical fitness of girls in the school environment, considering individual characteristics and initial functional state.

Changes in the functional parameters of the cardiovascular system

CVS indicators showed clear adaptive changes in response to the aerobic programme, with more pronounced positive dynamics in girls with a high level of motor activity. They showed a decrease in resting heart rate, faster recovery after exercise, and improved integral performance indicators, which was reflected in an increase in HRR1 and a decrease in the Ruffier-Dixon Index calculated using equations (1-3). In the low-activity group, the changes were more moderate, but also reflected the development of an adaptive response. The systematised data are presented in Table 4.

Table 4. Functional indicators of participants with different levels of motor activity ($M \pm SD$)

Indicator	Stage	Low activity (*n* = 17)	High activity (*n* = 13)
Resting HR, bpm	Beginning	82 ± 6	79 ± 5
	End	76 ± 5	70 ± 4
Post-exercise HR, bpm	Beginning	158 ± 10	152 ± 9
	End	146 ± 8	136 ± 7
HRR1, bpm	Beginning	18 ± 4	22 ± 5
	End	26 ± 5	34 ± 5
Ruffier-Dixon Index, C.U.	Beginning	13.4 ± 2.1	11.8 ± 1.9
	End	10.5 ± 1.8	8.3 ± 1.6

Source: compiled by the authors

The data obtained showed a gradual improvement in the functional state of the CVS in response to the aerobic programme, but the nature and pace of changes depended on the initial level of motor activity. The most significant marker of adaptation was a decrease in resting heart rate, which reflected the economisation of cardiac activity. In the high – activity group, the indicator decreased from 79 ± 5 to 70 ± 4 bpm (-11.4% decrease), while in the low-activity group-from 82 ± 6 to 76 ± 5 bpm (-7.3% decrease). This indicated an increase in the stroke volume of the heart and a strengthening of parasympathetic regulation, which is characteristic of aerobic fitness. A more pronounced decrease in girls with high activity indicated an initially better ability for central haemodynamic adjustment, which is consistent with the position on the dependence of the rate of adaptation on the initial functional level. Post-exercise heart rate showed a similar trend: in the high-activity group, the indicator decreased from 152 ± 9 to 136 ± 7 bpm (-10.5%), while in the low-activity group-from 158 ± 10 to 146 ± 8 bpm (-7.6%). A decrease in peak heart rate after standard exercise indicates an economisation of the heart response due to increased aerobic energy supply, improved oxygen delivery to working muscles, and more efficient use of oxidative substrates. This decrease reflects a lower level of internal physiological load under the same external stimulus, and its interpretation as signs of training adaptation is based on scientific data describing the corresponding cardiorespiratory changes in children and adolescents (Armstrong *et al.*, 2011).

HRR1 has become a key marker of recovery processes. In girls with high activity, it increased from 22 ± 5 to 34 ± 5 bpm (+54.5%), which indicates a sharp acceleration in the restoration of vegetative balance and more effective switching of regulation from sympathetic to parasympathetic after stopping the exercise. In the low-activity group, the increase was less significant: from 18 ± 4 to 26 ± 5 bpm (+44.4%). In the literature, high HRR1 values are associated with more efficient post-exercise recovery processes, which are manifested by a faster decrease in metabolic shifts and stabilisation of haemodynamic parameters (Buchheit, 2014). The Ruffier-Dixon Index showed the most integral improvement. In the high activity group, the value decreased from 11.8 ± 1.9 to 8.3 ± 1.6 C.U. (-29.7%), while in the low-activity group – from 13.4 ± 2.1 to 10.5 ± 1.8 C.U. (-21.6%), which, although it indicated positive dynamics, left this group within the limits of lower functional indicators. A decrease in the index reflects a simultaneous decrease in resting heart rate, a decrease in peak heart rate, and an improvement in the recovery rate, i.e., an integral restructuring of CVS activity. The most intense dynamics was observed during the first month, after which the rate of improvement decreased. This indicates the phasicity of adaptation: at the initial stage, functional mechanisms predominate (neurohumoural regulation, changes in cardiac output), while structural changes, in particular, an increase in capillarisation and an increase in mitochondrial density, are formed much more slowly, which is confirmed by previous scientific data (Blagrove *et al.*, 2018). Thus, the results confirmed that a higher initial level of motor activity provides a faster and more complete implementation of the adaptive mechanisms of CVS, which determines the training efficiency and aerobic potential of the body.

Features of adaptive changes depending on the level of motor activity

Analysis of the results showed that adaptive changes in response to the aerobic programme were differentiated depending on the initial level of motor activity. A comparison of the rates of increase in physical fitness indicators showed that girls with high motor activity demonstrated a more intense training response, which is characteristic of both aerobic endurance and muscular endurance and speed-strength abilities. Summary data on growth are shown in Figure 1, which allows visually comparing the dynamics between groups and determining the dominant components of physical fitness.

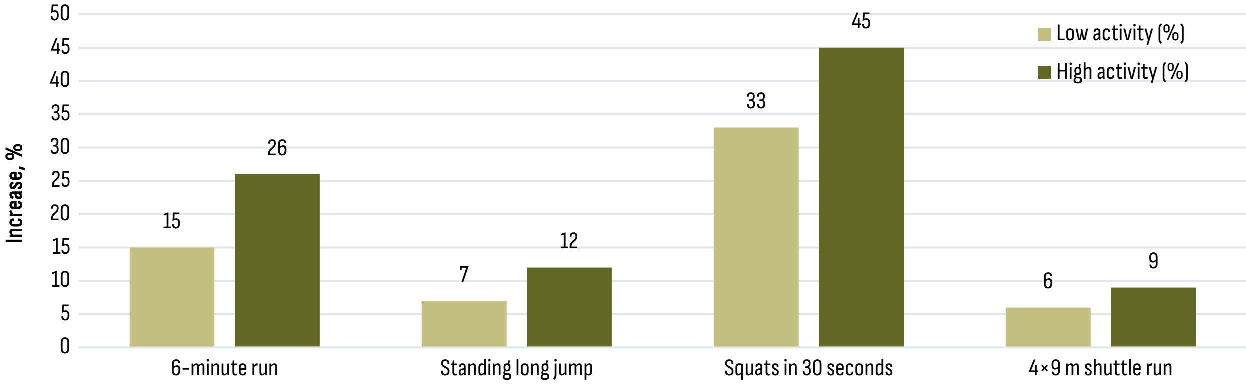

Figure 1. Increase in physical fitness indicators among adolescent girls

Source: created by the authors

The structure of changes in physical fitness showed that the greatest increase was observed in the 30-second squat test: +33.3% in the low-activity group and +45% in the high-activity group. This indicated an effective development of muscle endurance in the lower extremities due to regular repetition of cyclic loads of medium intensity. In the 6-minute run, the increase was +15.9% and +25.6%, respectively, which also confirmed a more pronounced aerobic adaptation in physically active girls. To a lesser extent, the changes affected coordination abilities (4×9 m shuttle run), where the increase was lowest in both groups. This indicated a lower training sensitivity of this component to the predominantly aerobic effects of the programme. Analysis of CVS functional indicators allowed establishing even clearer differences between the groups. Generalised growth data are shown in Figure 2. The decrease in heart rate at rest and after exercise, and the improvement in HRR1 and Ruffier-Dixon Index were systemically higher in the high-activity group, which indicates a qualitative shift in the mechanisms of cardiovascular regulation. The most pronounced effect was recorded for HRR1 (+44.4% vs. +54.5%), reflecting a faster switch of the autonomic nervous system from sympathetic activation to parasympathetic recovery, which is confirmed by data from a study in which HRR is considered as a key marker of vagal control and fitness level (Stanley *et al.*, 2013). Improvement of the Ruffier-Dixon Index (-21.6% vs. -29.7%) in physically active girls indicated not only a better ability to maintain heart function under load, but also a reduction in energy costs for its implementation, which increases the functional efficiency of activities. In the low-activity group, the changes were gradual, which is associated with an initially lower level of adaptive reserves and slower development of cardiorespiratory mechanisms.

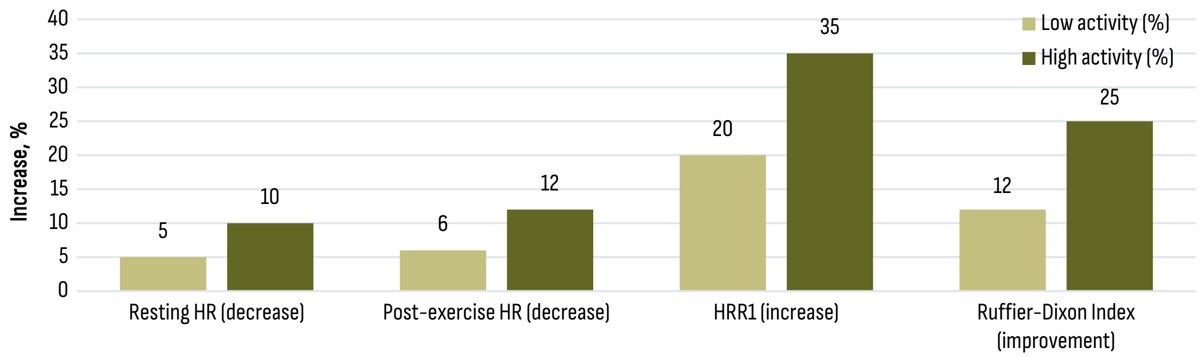

Figure 2. Increase in functional indicators of the cardiovascular system among adolescent girls
Source: created by the authors

The relationship between the degree of involvement in motor activity and adaptive changes was manifested in the form of statistically significant correlations, which allows not only stating the difference between groups, but also explaining the mechanisms through which the initial motor status affects the training response. The most pronounced association was established between the degree of motor involvement and the increase in the results of six-minute running ($r = 0.68$; $p < 0.01$), which indicates a high degree of dependence between previous motor involvement and the ability to increase aerobic endurance. This means that girls with higher PAQ-A already developed mechanisms for efficient oxygen use, a larger volume of functioning mitochondria, and better peripheral muscle perfusion, which provided a more intense adaptive effect during the programme. The negative association between PAQ-A and changes in resting heart rate ($r = -0.72$; $p < 0.01$) confirmed that high motor activity contributes to a more significant economisation of cardiac activity. A decrease in resting heart rate in physically active girls indicated an increase in stroke blood volume and an increase in vagal influence, that is, the heart performed the same work with less energy costs. This is a characteristic feature of a trained cardiovascular system.

The correlation of average strength between activity level and improvement in the Ruffier-Dixon Index ($r = -0.65$; $p < 0.05$) showed that physically active girls showed faster recovery after standard exercise and lower physiological cost of performing it. This reaction indicates a coordinated functioning of the cardiovascular and respiratory systems, which ensures more efficient recovery and faster elimination of metabolites. The association between PAQ-A and HRR1 ($r = 0.70$; $p < 0.01$) confirmed that it is the initial level of motor activity that significantly determines the rate of heart rate recovery after exercise. Higher HRR1 values in physically active girls indicated a rapid switch of the autonomic nervous system from sympathetic dominance to parasympathetic control, which is a sign of a high level of fitness and resistance to physiological stress. This allows interpreting PAQ-A as a sensitive predictor of the effectiveness of adaptation processes in the framework of physical education and recreation programmes. Comparison of the obtained correlations established a clear pattern: the higher the initial level of motor activity, the more intense and systematic adaptive changes are detected. This reflects a differentiated training sensitivity, where the same external influence causes a different response of the body depending on previous motor experience. The results confirm that the initial level of activity acts as a predictor of training effectiveness and can be used to predict the adaptive potential of adolescent girls.

The results show that systematic aerobic classes in extracurricular format, organised according to the principles of sports training (regularity, gradual increase in load, intensity control), contribute to the development of aerobic endurance and improvement of functional indicators of the cardiovascular system in adolescent girls. More pronounced adaptive changes in physically active students reflected the influence of previous motor experience, which is typical for sports training, where the developed training base provides a faster increase in functional capabilities. This was manifested in a greater increase in endurance and faster recovery from exercise, which corresponds to the body's response to an aerobic training stimulus in sports. The data obtained confirm the differentiated nature of adaptation, typical for sports activities, depending on the initial motor level.

Discussion

The results of the study showed an improvement in the indicators of physical fitness and functional state of the cardiovascular system in adolescent girls after an aerobic programme. The greatest changes were observed in the development of aerobic and muscular endurance, while coordination indicators underwent less pronounced shifts. The nature of adaptive changes differed depending on the initial level of motor activity: girls with high activity showed a greater increase in indicators and faster recovery after exercise compared to low-activity participants, which indicates a differentiated response of the body to the same training stimulus.

The improvement in physical fitness was manifested primarily in the increase in aerobic and muscular endurance: the result of six-minute running increased by +15.9% in the low-activity group and +25.6% in the high-activity group, and the indicator of squats in 30 seconds – by +33.3% and +45%, respectively. The dynamics of coordination abilities was lower: in the 4×9 m shuttle run, the reduction in execution time was 5.5% and 8.8%. This adaptation structure is consistent with the conclusions of P. Stricker *et al.* (2020), who emphasised that in children and adolescents, overall training load stimulates the development of aerobic and muscular endurance, while improving coordination abilities requires the use of specially organised motor tasks with increased sensory-motor complexity. This nature of adaptation was consistent with data by M. Bratic *et al.* (2022), where a regular aerobic programme in girls caused an increase in endurance and muscle performance due to repeated cyclic loads of moderate intensity, which confirms the effectiveness of such a training approach. The study showed slower changes in speed coordination tests, which correlates with lower training sensitivity of this component.

The results obtained were consistent with the data by T. Petrušič *et al.* (2022), where school intervention contributed to improved physical fitness in girls aged 12-14, with the greatest increase in endurance, confirming the importance of the aerobic component in shaping the training response. However, the researchers noted a higher increase in speed and strength indicators, which partially does not coincide with the identified patterns in this study and may be conditioned by the game format of classes. The growth ratio between the groups was consistent with observations of D.D. Cohen *et al.* (2021), where a higher initial level of activity was associated with more intense training progress, confirming the role of initial motor status in the development of adaptive mechanisms. C. Romero *et al.* (2021) showed that the development of speed, strength, and coordination indicators in adolescents requires specific stimuli, which explains the minimal dynamics of shuttle running in this study.

Functional status indicators showed positive changes: resting heart rate decreased by 7.3% in the low-activity group and 11.4% in the high-activity group, HRR1 increased by 44.4% and 54.5%, respectively, while the Ruffier-Dixon Index improved by 21.6% and 29.7%. The decrease in peak heart rate after exercise was more pronounced in girls with high activity – 16 bpm versus 12 bpm, which reflects an increase in cardiac activity and an increase in recovery efficiency. The consistency of these changes can be traced with the data by E.S. Cowley *et al.* (2021), which showed that regular motor activity in adolescents contributes to a better physiological response to exercise. The researchers emphasised the role of psychosocial factors, which may partly explain the stable differences between groups. I. Csecs *et al.* (2020) indicated that systematic training contributes to the improvement of structural and functional parameters of the cardiac apparatus in adolescents. The researchers' observation of the gradual development of cardiac adaptations differs from the faster functional changes recorded in the current study.

According to the conclusions of T. Harju (2025), aerobic programmes enhance vagal effects on heart rate in adolescent girls, which is consistent with a more pronounced increase in HRR1 in the high motor activity group recorded in the present study. This mechanism may explain the higher rate of post-exercise recovery characteristic of participants with better initial fitness levels. The analysis by S.K. Hunter *et al.* (2023) confirmed that autonomous regulation of cardiac activity in girls is characterised by high plasticity in response to exercise. The researchers emphasised sex-specific mechanisms of heart rate control, which is consistent with the resulting HRR1 dynamics. Results of the study by M.M.R. Iñigo-Vollmer & M. Fernández-del-Valle (2023) demonstrated that regular aerobic exercise in girls provides a systemic improvement in the mechanisms of cardiovascular performance. The researchers emphasised the importance of adequate training intensity, which corresponds to a more effective improvement in the Ruffier-Dixon Index in the high activity group.

The established correlations showed a relationship between the level of motor activity and the scale of adaptive changes: the strongest associations were observed between PAQ-A and endurance gain ($r = 0.68$; $p < 0.01$) and HRR1 ($r = 0.70$; $p < 0.01$), while a decrease in resting heart rate correlated at $r = -0.72$ ($p < 0.01$). The correlation with the Ruffier-Dixon Index ($r = -0.65$; $p < 0.05$) reflected the integral nature of the response. The results were consistent with data by H.W. Landgraff *et al.* (2021), who showed that adolescents with a higher training background show a greater increase in maximum oxygen consumption, which supports the found association of PAQ-A with aerobic endurance. The researchers noted broad variability between individuals, which coincides with the heterogeneity of changes in the low-activity group. L.D. McGarrigal *et al.* (2025) stated that the development of motor function in girls depended on the initial level of motor activity involvement, which coincides with the established association between PAQ-A and increased muscle endurance. However, the researchers emphasised the age-related features of maturation, which had minimal impact due to the narrow age range in the study.

Observations of E. Papaevangelou *et al.* (2023) confirmed that female athletes with higher training load showed a more pronounced improvement in cardiorespiratory function during the season, which is consistent with the identified HRR1 correlations. However, researchers pointed out the role of the specificity of the sport, which was not relevant for the school contingent. The effectiveness of personalised programmes is determined by participants' individual activity levels, which is consistent with the identified association between PAQ-A and recovery rates reported by P. Petrovics *et al.* (2025). The researchers noted that motivational factors change the response to stress, which can also affect the resulting correlations. The data obtained by L. Plavsic *et al.* (2020) showed that systematic training leads to improved aerobic function in girls with different baseline fitness levels, but faster changes occur in those with higher baseline activity, which is fully consistent with the results obtained for PAQ-A.

The results show adaptive changes characteristic of adolescence to systematic aerobic exercise, which are used in physical education and sports practice, in particular, improving cardiorespiratory regulation and increasing the training response in physically active girls. According to Y.S. Rajpoot *et al.* (2025), in young female athletes, the recovery rate and sensitivity of autonomous heart rate regulation increase with increasing training intensity, which is consistent with higher HRR1 values in physically active girls. The researchers also demonstrated that cardiorespiratory responses in female athletes are more economical under conditions of repeated loads – a similar trend was observed in girls with high PAQ-A.

Additionally, R.S. Oliveira *et al.* (2018) found that higher levels of motor activity in adolescents are associated with more effective autonomous regulation of cardiac activity and favourable indicators of cardiorespiratory functioning, which may explain a more expressive training response in the high-activity group. The study by

A.Z. Skouras *et al*. (2023) proved that aerobic and resistive loads were shown to cause systemic changes in cardiovascular reactivity, which is consistent with an improvement in the Ruffier-Dixon Index and a decrease in heart rate in the study groups. The researchers noted that the effect of regular training is manifested in increasing the effectiveness of recovery mechanisms – a similar effect was recorded in the group of high activity. The increase in endurance and motor performance in physically active girls was consistent with the results obtained by Z. Wang *et al*. (2024), who showed that a combination of functional strength and aerobic training provides improvements in aerobic endurance and overall motor form in adolescents.

According to V.M.R. Weber *et al*. (2024), girls' regular participation in sports and wellness programmes is associated with increased cardiorespiratory fitness, which is consistent with higher results of high activity in HRR1 and resting heart rate. The researchers noted that systemic training stimuli contributed to the development of stable physiological adaptations, which correlated with the differentiated training response obtained in the study. Discussion of the results showed that the established adaptive changes in physical fitness and functional indicators of the cardiovascular system are consistent with data from other scientific studies that describe the positive effects of aerobic exercise on endurance, heart rate, and recovery rate in adolescent girls. The revealed relationship between the level of motor activity and the amount of training shifts corresponds to the models of differentiated training sensitivity described in sports science.

Conclusions

Analysis of the dynamics of physical fitness showed that the aerobic programme caused a gradual increase in endurance, strength, and coordination capabilities, but the rate of changes was differentiated depending on the initial motor status. In girls with high activity, the increase in the distance of six-minute running reached +25.6% compared to +15.9% for low activity, and the number of squats increased by +45% against +33.3%. Instead, the improvement in shuttle running time remained moderate (-8.8% and -5.5%, respectively), reflecting a lower specific sensitivity of coordination abilities to an aerobic training stimulus. The totality of results showed that the initial level of activity determines the scale and rate of positive morphofunctional changes in a single programme. The functional response of CVS also demonstrated a gradual nature of adaptation: although both groups had positive changes, their magnitude was higher in physically active girls. The decrease in resting heart rate was -11.4% in high activity versus -7.3% in low activity, while the increase in HRR1 reached +54.5% compared to +44.4%. The Ruffier-Dixon Index improved by +29.7% and +21.6%, respectively, reflecting more efficient integration of cardiovascular regulation mechanisms, faster recovery, and lower physiological stress under standard exercise. Thus, training adaptation was not only quantitative, but also qualitative in nature, increasing with increasing initial activity.

Correlation analysis deepened the results obtained, confirming that the level of motor activity is a predictor of training effectiveness. The strongest associations were found between PAQ-A and endurance gain in six-minute running ($r = 0.68$; $p < 0.01$) and HRR1 ($r = 0.70$; $p < 0.01$), while a negative correlation with changes in resting heart rate ($r = -0.72$; $p < 0.01$) and the Ruffier-Dixon Index ($r = -0.65$; $p < 0.05$) reflected economisation of cardiac activity in more active girls. The consistency of these connections indicates the systemic influence of the initial motor mode on the scale and course of adaptive processes, which confirms the concept of training sensitivity of adolescents. The combination of quantitative changes in physical fitness, functional responses and established correlations confirms that the aerobic programme contributed to the development of differentiated adaptive shifts, the scale and direction of which were determined by the initial level of motor activity

The prospects for further research are to specify the solution of the problem by including a control group to correctly determine the training effect depending on age and individual variability, and to expand the sample by gender, age and type of educational institutions, which will increase the significance of the results obtained. Further research should focus on comparing the effectiveness of different aerobic, strength, and combined programmes, and analysing how baseline physical activity levels modify training responses in adolescents in different socio-educational contexts.

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Conflict of Interest

None.

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Аеробні навантаження як чинник адаптаційних змін у фізичному та функціональному станах дівчат підліткового віку

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Анотація. Мета дослідження – комплексна характеристика зміни показників фізичної підготовленості та функціональних можливостей дівчат підліткового віку залежно від рівня рухової активності під впливом аеробних навантажень. Дослідження проводилося на базі Переяславської гімназії № 3 (Київська область) упродовж 17 березня – 25 травня 2025 року та включало аеробну програму з двома етапами вимірювання, що дозволило проаналізувати динаміку фізичної підготовленості й функціональних показників серцево-судинної системи дівчат-підлітків із різним рівнем рухової активності. Було з'ясовано, що у групі високої активності дистанція шестихвилинного бігу зросла з 900 ± 100 м до 1 130 ± 90 м (+25,6 %), тоді як у низької активності – з 820 ± 95 м до 950 ± 85 м (+15,9 %). Кількість присідань за 30 с збільшилася на +45 % (із 20 ± 4 до 29 ± 3) проти +33,3 % (із 18 ± 4 до 24 ± 3). Показники човникового бігу 4×9 м покращилися помірно: -1,1 с у високої активності та -0,7 с у низької. Функціональні зміни серцево-судинної системи проявилися зниженням частоти серцевих скорочень у спокої на -11,4 % та -7,3 % відповідно, приростом відновлення за першу хвилину на +54,5 % проти +44,4 %, а також зниженням індексу Руф'є-Діксона на 29,7 % і 21,6 %, що відображає покращення функціонального стану. Кореляційний аналіз підтвердив, що рівень рухової активності статистично пов'язувався із масштабом адаптаційних змін ($r = 0{,}68 - 0{,}72$; $p < 0{,}01$). Таким чином, вихідний руховий статус визначав тренувальну чутливість дівчат-підлітків і впливав на характер змін фізичної підготовленості та функціональних показників. Отримані дані можуть бути використані вчителями фізичної культури, тренерами та фахівцями оздоровчих програм для диференціації навантаження з урахуванням вихідного рівня рухової активності дівчат

Ключові слова: рухова активність; тренувальний вплив; м'язова витривалість; швидкість відновлення; серцево-судинна система; дівчата 13-15 років; фітнес-програми