Journal of Vasyl Stefanyk Precarpathian National University
http://journals.pnu.edu.ua
Vol. 9, No. 1 (2022), 219-226

UDC 796.015.6:796.012.62
doi: 10.15330/jpnu.9.1.219-226

INFLUENCE OF RESPIRATORY EXERCISES ON THE FUNCTIONAL STATE OF THE CARDIOVASCULAR SYSTEM UNDER DIFFERENT PHYSICAL ACTIVITIES OF STUDENTS

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Abstract. The article stresses that the state of the cardiovascular system determines the level of physical performance. Maintaining the required level of metabolic processes is necessary for efficient mechanisms of energy supply and dynamic work. The researcher proves that activation of respiratory function contributes to such support. Under the influence of systematic breathing exercises in the body develops a set of structural and functional changes aimed at optimizing the functioning of the whole organism and its individual systems. The study involved 35 lyceum students aged 14 years, who were engaged in the developed system for 1.5 years. Each lesson consisted of six parts. In the first, third and fifth parts, they performed exercises with dynamic, and in the second and fourth – with static load. In the first three parts they were combined with breathing exercises with increasing duration of individual phases of breathing, in 4-6 parts – only with deepening of exhalation. The sixth part (relaxation) was performed in a horizontal position. The purpose of the work is to determine the impact of breathing exercises during each part of the lesson on the activity of the cardiovascular system. It has been established that certain features of fatigue and recovery during different types of muscular work in a specific sequence are a reliable physiological basis for improving the health and training effect of physical training in combination with breathing exercises. The results of the experiment on the implementation of our system of health-improving training sessions of respiratory gymnastics prove that changes in work power, nature of muscle contractions and body position during training create conditions for improving adaptive compensatory reactions to different types of loads.

Keywords: respiratory exercises, cardiovascular system, physical activity, cardio regulation, relaxation, heart rhythm.

1. INTRODUCTION

Functional reserves of the body affect the level of physical performance, which is largely determined by the state of the cardiovascular system [3], [6]. Unlike static, dynamic work depends on the efficiency of energy supply mechanisms and requires the maintenance of the required level of metabolic processes. This necessitates a significant activation of the function of other organs, in particular, the respiratory system [4], [9]. It is known that a threefold increase in metabolism leads to severe oxygen starvation, as the safety factor of tissues for oxygen transport is 3 units. [2], [6], [8]. In the case of intense physical activity, the utilization rate of oxygen increases 3 times, while the minute volume of blood (MVb)can increase compared to rest at 6 times. As a result, the supply of oxygen to the tissues increases approximately 18 times. In trained people, such an increase in energy supply allows to increase the level of metabolism by 15-20 times compared to the level of basal metabolism [5], [7]. This indicates the feasibility of regular exercise with priority use of respiratory exercises that increase the level of metabolic processes, which increases with increasing level of physical activity. Under the influence of systematic breathing exercises in the body develops a set of structural and functional changes aimed at optimizing the functioning of the whole organism and its individual systems. The cardio-respiratory system is no exception, the optimization of which is a necessary condition for achieving a high level of somatic health [1], [2].

Experimental confirmation of the effectiveness of the impact on the cardiovascular system (CVS) was obtained by our system of health-training classes in respiratory gymnastics [7]. However, the studies did not allow to determine the patterns and features of the impact on the circulatory system of different in shape and strength of physical activity with their specific sequence during the lesson.

The aim of the work is to determine the influence of respiratory exercises during each part of the lesson on the activity of the cardiovascular system.

2. RESULTS AND DISCUSSION

2.1 Research methods and organization

Each lesson consisted of six parts. In the first, third and fifth parts, they performed exercises with dynamic, and in the second and fourth – with static load. In the first three parts they were combined with breathing exercises with increasing duration of individual phases of breathing, in 4-6 parts – only with deepening of exhalation. The sixth part (relaxation) was performed in a horizontal position.

The study involved 35 lyceum students aged 14 years, who were engaged in the developed system for 1.5 years.

The dynamics of the main hemodynamic parameters (heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP)), as well as systolic volume blood (SVb) and MVb were studied throughout the session, at rest in horizontal and vertical body positions, after each part of the session, immediately after exercise and during recovery.

The method of variation was used to analyze heart rhythm [4], [6], [7]. Variation pulsegrams were recorded on a 12-channel Kettler electrocardiograph in the second standard lead using CardioLab +. Continuous recording of 100 cardio cycles was performed by counting R-R intervals. To analyze the heart rate, we determined the indicators that characterize the level of functioning of the cardio system: mode (MO), mode amplitude (AMO%), as well as indicators determining the degree of variation - maximum (MxRR) and minimum (MnRR) amplitude of cardio intervals, , variational amplitude (ΔRR) and the derived indicator - the index of voltage of regulatory systems (IN) [4].

All indicators are processed by non-parametric statistics.

2.2 Results of the research

Before training in the horizontal position of the body heart rate is 61.88 ± 2.82 beats / min., In the vertical - 75.23 ± 2.91 beats per minute (b/min), systolic and diastolic blood pressure – respectively 121.52 ± 1.68 / 56.71 ± 2.05 and 110.49 ± 2.32 / 69.77 ± 3.51 mmHg. As can be seen from Table 1, changes in body position also affected the indicators of SVb and MVb. In the horizontal position of the body SVb is 80.41 ± 2.30 ml, and in the vertical - decreases by 33.21 ± 0.33% and is equal to 62.55 ± 2.52 ml. Similar changes were observed in the indicators of MVb (they decrease by 7.69 ± 0.26%.

Parts of the lesson	HR, b/min	SBP, mmHg	DBP, mmHg	SVb, ml	MVb, l/min
Before the lesson (lying down)	61,88±2,82	121,52±1,68	56,71±2,05	80,41 ±2,30	4,65±0,22
Before the lesson (standing)	75,23±2,91	110,49±2,32	69,77±3,51	62,55±2,52	4,58±2,64
First	143,82±8,32	160,65±3,58	64,76±3,21	94,12±1,65	14,2±0,67
Second	175,33±3,43	182,87±3,55	59,53±1,54	108,87±3,48	19,88±1,31
Third	135,05±4,99	165,55±2,44	68,57±2,39	92,81±3,82	12,67±0,96
Fourth	64,49±3,67	121,09±2,44	60,76±2,54	78,77±3,56	5,15±0,44
Fifth	80,26±2,43	112,74±2,59	67,13±3,34	73,15±2,44	5,74±0,52
Sixth	61,95±2,65	114,78±1,66	59,76±1,67	76,88±2,11	4,55±0,22
2 min after class	73,08±2,43	112,34±2,75	68,16±2,65	67,9±2,76	5,11±0,68

Tab. 1. Indicators of hemodynamics at rest and after exercise (M ± m)

After a 15-20-minute warm-up, which consists of various types of walking, slow running, exercise and dance movements, heart rate increased to 143.82 ± 8.32 b / min, which is 96.11 ± 0.2% more than in a standing position before exercise. SBP increases by 45.92% (from 110.49 ± 2.32 to 160.65 ± 3.58 mmHg), and DBP decreases by 6.74% (from 69.77 ± 3.51 to 64 , 76 ± 3.21 mmHg). At the same time SVb increases 1.5 times, MVb – 2.92 times ($p < 0,05$). According to some authors [2], [4], [5], physical activity at a heart rate of 140-160 b / min is characterized as aerobic. To increase the training effect during this load, the duration of exercise should be at least 5 minutes, resulting in positive changes occur in the lipoprotein composition of the blood, but not detected in the maximum oxygen consumption (VO2 max) and the threshold of anaerobic metabolism (AT) [2].

In the second part of the lesson (20-25 minutes) the students performed exercises from the starting position standing on all muscle groups of the current method. During this time, the heart rate increases by another 20.98% and is 175.33 ± 4.43 b / min. At the same time SBP increases by 9.25%, while DBP decreases by 7.51% ($p < 0.05$).

Compared with the previous load, SVb increased by 17.52 ± 1.14%, and MVb by 43.61 ± 0.86%. Therefore, the work on this section of the class was mainly performed in aerobic-anaerobic mode. References data indicate that such a training regime is primarily accompanied by an increase in VO2 max and an increase in AT [1].

In the third part of the lesson (20-25 minutes), exercises were performed on all muscle groups from the starting positions sitting, lying down, kneeling, etc. HR in this case is 135.05 ± 4.99 b / min, which is 24.11% less than in the previous part of the lesson and corresponds to the aerobic nature of the load [5].

The blood pressure was close to the first part of the lesson and was 155.5 ± 2.44 / 68.57 ± 2.39 mmHg, i.e. SBP decreased by 9.41 ± 0.81%, and DBP increased by 12.86 ± 0.62% compared to the previous part of the lesson.

In the fourth part of the lesson the students performed static stretching exercises in combination with breathing for 35-40 minutes. Holding each pose lasted from 1.5 to 3.0 minutes. The decrease in heart rate to 64.49 ± 3.67 b / min was recorded during the first pose and with small fluctuations (± 5.5 b / min) its indicators were maintained during complex exercises. Blood pressure is restored to initial values, its values are 121.09 ± 2.44 / 60.76 ± 2.54 mmHg. SVb decreased compared to the previous part of the session by 20.2 ± 0.75% and amounted to 78.77 ± 3.56 ml, which is 1.87 ± 0.2%

less than the initial level in the same body position. MVb decreased by 14.73 ± 0.81 l / min compared to the second part and by 7.52 ± 0.33 l / min – with the third.

Compared with the initial level, the MVb indicator was higher by only 0.50 ± 0.3%, i.e. the difference between the indicators is unlikely (P> 0.05).

Thus, all the obtained indicators of hemodynamics indicate that static work in combination with breathing exercises helps to restore the functions of the CVS.

In the fifth part of the lesson, dynamic exercises were performed in a sitting position for 10-15 minutes. Then in a standing position heart rate and blood pressure were measured. Immediately after the end of the class, the heart rate was 80.26 ± 2.43 b / min, which is 6.83 ± 0.3% more than the initial level in the same body position. SBP decreased by 2.8 ± 0.3% of the indicators after relaxation, but was higher than the initial level by 0.92 ± 0.1%. DBP increases to 67.13 ± 3.34 mmHg, but its indicators were 5.79 ± 0.2% lower than the original data (p <0.05).

At 12-15 minutes of relaxation in a supine position (sixth part of the session), heart rate decreases by 1.05 ± 0.2% (p> 0.05). At the same time SBP decreases only by 3.88 ± 0.47%, while the DBP remains unchanged. Indicators of SVb and MVb decreased by 75.76 ± 1.8% and 4.85 ± 0.2%, respectively, and became lower than the initial level at the same body position.

2 minutes after the end of the lesson, all hemodynamic parameters reached baseline. The difference between them before and after 2 minutes of recovery is unlikely (p> 0.05). The rapid recovery of all hemodynamic parameters after exercise can be explained by the fact that these processes began in the fourth part of the session, i.e. about 30-40 minutes before the end.

The slight increase in heart rate in the fifth part is due not so much to the exercise, which took place at a slow pace and was mainly aimed at developing flexibility, but to a change in body position.

Thus, the analysis of hemodynamic parameters throughout the lesson allows us to conclude that the first three parts of the class in aerobic and aerobic-anaerobic regime have a training effect on CVS, and breathing exercises and relaxation accelerate the recovery process.

When analyzing the dynamics of cardio regulation (*Table 2*), it was found that at rest the maximum value of cardiocycles (MxRR) corresponded to the zone of normergic regulation, and the minimum (MnRR) – adrenergic zone, which indicates an increase in sympathicotonic effect on autonomic contours. However, the range of variability (ΔRR) in all lyceum students was high - 0.29 ± 0.05 s, which corresponds to the reference values [6].

Part of the lesson	**MxRR**	**MnRR**	**ΔRR**	**MO**	**AMO, %**	**IN**
Before the lesson	0,87±0,09	0,61±0,04	0,29±0,05	0,77±0,03	25,8±3,55	53,41±8,44
First	0,62±0,03	0,56±0,04	0,09±0,02	0,59±0,02	39,40±1,25	432,80±45,22
Second	0,60±0,02	0,48±0,02	0,25±0,01	0,55±0,03	42,5±0,89	266,42±27,63
Third	0,56±0,03	0,51±0,02	0,12±0,01	0,45±0,03	88,5±1,95	791,10±71,80
Forth	0,66±0,02	0,59±0,02	0,23±0,02	0,61±0,01	82,40±1,81	489,40±28,71
Fifth	0,88±0,02	0,63±0,03	0,35±0,01	0,69±0,02	76,5±1,83	174,30±19,87
Sixth	0,99±0,05	0,55±0,08	0,49±0,03	0,65±0,03	27,80±4,60	46,3±7,12

Tab. 2. Indicators of cardio regulation at rest and throughout the lesson (M ± m)

The value of Mo is 0.77 ± 0.03 s and corresponds to the average value of cardio cycles. AMo is equal to 25.8 ± 3.55%, and IN – 53.41 ± 8.44, which corresponds to the normotonic type of cardio regulation.

After the first part of the session, MxRR and MnRR significantly decreased, and ΔRR was 0.09 ± 0.02 s, which indicates the predominance of adrenergic effects on the pacemaker. The value of Mo was 0.59 ± 0.02 s, which is 29.9% less than before exercise, and indicates a decrease in the activity of the humoral channel of heart rate regulation. AMO, which characterizes the sympathetic effects on cardio regulation, increases to 39.4 ± 1.25%. IN increases 8 times, which, according to studies [6], [8] characterizes the processes of the involvement of CVS during warm-up.

After the second part of the lesson, the adrenergic effects increase, which is manifested by a decrease in MxRR by 0.02 s, and MnRR – by 0.08 s compared to the previous part of the lesson. However, the range of variability increases to 0.15 ± 0.01 s. A slight increase in Mo (0.04 s) cannot characterize the activation of humoral regulation [6], [8]. Probably increase ($p < 0.01$) AMo indicators in the second part of the lesson compared to the first, which is also a sign of a further increase in adrenergic effects. The IN also decreases significantly (on average by 39% – up to 266.42 ± 27.63).

Therefore, the obtained indicators may point to the stabilization of cardio regulation after warm-up and during exercise in aerobic and aerobic-anaerobic regimes in an upright position.

In the third part of the session, MxRR decreases insignificantly (up to 0.56 ± 0.03 s), and MnRR increases to 0.48 ± 0.02 s, thus the range of variability becomes smaller by 0.02 s. Significantly increased ($p < 0.01$) compared to the second part of the class AMo (88.5 ± 1.95%). All this characterizes the further growth of adrenergic effects on cardio regulation. The activity of the humoral channel of heart rate regulation remained at the previous level. Significantly changed ($p < 0.01$) IN – it increased to 791.1 ± 71.8, which indicates an increase in excitation of the circulatory system. Apparently, such features of cardio regulation are associated with muscle work in a horizontal position, when due to the positive inotropic effects on the heart increases the strength and rate of myocardial contraction. According to M. Vanyushin (2003) [4], in which IN 100-900, moderate stress develops, which does not lead to significant changes in homeostasis.

After the fourth part of the class, the maximum values of cardio cycles increased by 24.8% and the minimum values – by 27.8%. The scope of variability increased by 29%. The humoral channel of cardio regulation was significantly activated, Mo increased to 0.61 ± 0.01 s, which is 21.8% more than in the previous part of the lesson. Adrenergic effects decreased slightly (by 7.2%). Significantly decreased IN. As can be seen from *Table 2*, this is mainly due to the activation of the humoral channel of heart rate regulation and partially cholinergic effects, which can be explained by the horizontal position of the body during exercise, and activation of endocrine glands during static exercise in combination with deep exhalation.

During the relaxation break in the fifth part of the session, the dynamics of all indicators point to further recovery processes in the cardio regulation system.

Probably ($p < 0.05$) MxRR values increased (up to 0.88 ± 0.02 s). Changes in MnRR were insignificant, but the magnitude of variability increased to 0.26 ± 0.01 s and was almost equal to baseline, indicating activation of the parasympathetic part of the autonomic regulation of heart rhythm. The indicators of MO are 0.69 ± 0.02, i.e. an increase of 10.2% compared to the previous part of the lesson. An increase in Mo by only 4.1% indicates that it does not reach the initial data and characterizes the activation of the humoral channel of regulation of cardio intervals.

The value of AMo decreased by 7.1% compared to the data in the fourth part of the lesson, but was higher than the original data, which can be described as a tendency to weaken adregergic effects. After relaxation, the IN decreased significantly (to 174.3 ± 19.87), which is 2.8 times less than after dynamic exercise without respiratory exercises ($p < 0.01$).

After the fifth part of the lesson, the humoral effects remain at the previous level, and the nervous regulation of the heart rhythm changes significantly. Compared to the data of the previous part of the lesson, a slight increase in MxRR and a decrease in MnRR leads to a probable increase in the range of variability ($p < 0.05$). AMo and IN are significantly reduced, their indicators are almost equal to the baseline. In the fourth part of the lesson in the cardio regulation system the cholinergic channel of influence on the "pacemaker" prevails. The analysis of the obtained results (Table 2) made it possible to determine the influence of different types of physical activity on the type of cardio regulation. It is known that the period of exercise is characterized by a significant increase in adrenergic effects [2], as evidenced by a decrease in MxRR, MnRR, ΔRR and Mo with increasing AMo and IN.

Slight increase in adrenergic effects and decrease in IN during exercise in aerobic and aerobic-anaerobic regimes in the vertical position of the body indicate the body's adaptation to exercise. Changing body position to horizontal during aerobic exercise contributes to a significant increase in adrenergic effects on cardioregulation. The indicators of ΔRR decrease, AMo and IN increase significantly.

At a high and submaximal level of power of physical work (the second and third parts of the lesson) no changes were recorded in the humoral channel of heart rate regulation. The value of Mo significantly ($p < 0.05$) decreases during exercise (warm-up) and does not change during the entire period of specific loads.

Along with this, in the process of performing breathing exercises there is a probable ($p < 0.05$) increase in Mo, which indicates the activation of the humoral channel of heart rate regulation. In addition, there is a tendency to increase cholinergic effects. The indicators of ΔRR increase and AMo and IN decrease. A significant increase in cholienergic effects on the pacemaker is natural for relaxation. Significantly increases the indicators ΔRR, Mo and decreases AMo and IN.

Thus, starting from the fourth part of the session, cardio regulation is gradually restored, due to the activation of the humoral channel of regulation during breathing exercises and relaxation, and there is a full recovery at the end of the session with increased vagal regulation.

3. CONCLUSIONS

Taking into account the studied information and results of conducted research we attempt to draw the following conclusions:

1. Alternation of physical activity of different levels of intensity during exercise causes a restructuring of the cardiovascular system, which depends on their sequence.

2. The main training effect on the circulatory system was recorded during dynamic exercises in aerobic and aerobic-anaerobic regimes.

3. Changing the power of work, the nature of muscle contractions and body position during exercise during the session create conditions for improving the adaptive-compensatory reactions of the body to different types of loads.

4. Respiratory (breathing) exercises throughout the session and relaxation at the end of the session contribute to a significant increase in recovery processes after exercise.

5. Identified features of fatigue and recovery during different types of muscle work in a specific sequence is a reliable physiological basis for improving the health and training effect of physical activity in combination with breathing exercises.

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Received: 15.02.2022 ; **revised:** 27.03.2022.

Серман Тарас. Вплив дихальної гімнастики на функціональний стан серцево-судинної системи при різноплановій фізичній активності учнів. *Журнал Прикарпатського університету імені Василя Стефаника,* **9** (1) (2022), 219–226.

У статті наголошено, що стан серцево-судинної системи визначає рівень фізичної працездатності, підтримка необхідного рівня обмінних процесів необхідна для ефективних механізмів енергопостачання та динамічної роботи. Автор доводить, що такій підтримці сприяє активація дихальної функції. Під впливом систематичної дихальної гімнастики в організмі розвивається комплекс структурно-функціональних змін, спрямованих на оптимізацію функціонування всього організму та його окремих систем. У дослідженні взяли участь 35 ліцеїстів віком від 14 років, які займалися за розробленою системою протягом 1,5 років. Кожен урок складався з шести частин. У першій, третій і п’ятій частинах виконували вправи з динамічним, а в другій і четвертій – зі статичним навантаженням. У перших трьох частинах їх поєднували з дихальними вправами зі збільшенням тривалості окремих фаз дихання, у 4-6 частинах – лише з поглибленням видиху. Шосту частину (релаксація) виконували в горизонтальному положенні. Мета дослідження – визначити вплив дихальної гімнастики під час кожної частини уроку на діяльність серцево-судинної системи. Встановлено, що певні особливості перевтоми та відновлення при різних видах м’язової роботи в

певній послідовності є надійною фізіологічною основою для покращення оздоровчого та тренувального ефекту фізичних занять у поєднанні з дихальними вправами. Результати експерименту із впровадження нашої системи оздоровчих занять дихальної гімнастики доводять, що зміна робочої сили, характеру скорочень м'язів і положення тіла під час тренування створюють умови для покращення адаптивно-компенсаторних реакцій на різні види навантажень.

Ключові слова: дихальна гімнастика, серцево-судинна система, фізичне навантаження, кардіорегуляція, релаксація, серцевий ритм.