UDC 612.215:612.521.2:613.956

Somatotypological features of the functional state of the respiratory system and aerobic productivity in young people

B.O. Lisova, O.O. Horodetska, Yu.V. Kyrychenko

National Pirogov Memorial Medical University, Vinnytsya; e-mail: danotchka@gmail.com

In the context of the ongoing war in Ukraine, a comprehensive assessment of the medical and social situation remains a priority. Particular attention should be given to the functional state of the respiratory and cardiovascular systems in young people, as this age period is critical for the formation of the body's adaptive reserves. Despite the availability of studies on morphofunctional characteristics, the relationship between somatotype and aerobic performance in adolescence remains insufficiently understood. The aim of this study was to determine somatotypological characteristics, functional parameters of the respiratory system, and levels of aerobic performance in boys and girls of different constitutional types. A total of 58 clinically healthy individuals (25 boys and 33 girls aged 19-20 years) were examined. Somatotyping was performed using the Heath-Carter method, with classification into five groups: balanced, ectomorphic, endomorphic, endomorphic–mesomorphic, and mesomorphic types. Functional status was assessed by spirography (vital capacity, forced expiratory volume in 1 s, inspiratory reserve volume) and bicycle ergometry (PWC test, VO_2max). It was found that the mean values of respiratory and cardiovascular parameters were within physiological norms but showed a clear dependence on somatotype. Individuals with a mesomorphic somatotype demonstrated a more efficient breathing pattern (lower respiratory rate) and higher volumetric indicators. The ectomorphic somatotype was associated with lower blood pressure and higher relative aerobic capacity. The lowest values of vital capacity, inspiratory reserve volume, Tiffeneau–Wohlwill index, and physical performance indicators were observed in individuals with an endomorphic somatotype. Pronounced sex differences were observed: boys in all groups exhibited higher respiratory muscle strength and greater lung volume characteristics compared with girls. Thus, it was found that the constitutional factor significantly modifies the body's functional parameters. Individuals with an endomorphic somatotype appear to be at higher risk due to reduced respiratory reserve capacity and lower aerobic performance. These findings support the need for individualized health monitoring standards in young people, considering somatotype.
Key words: indicators of external respiration; somatotype; adolescence; spirometry; maximal oxygen consumption.

INTRODUCTION

A comprehensive assessment of the medical and social situation in Ukraine is a top priority in wartime conditions, due to the state of health of Ukrainians, which shows a worsening trend every day. Assessment of the cardiovascular and respiratory system can prevent complications and reduce mortality from these diseases. The study of external respiration functions is a significant component of the overall assessment of the health status of both adults and children.

Several works of domestic and foreign scientists are devoted to the study of the regularities in respiratory system formation and its functions [1-3]. However, there are still insufficiently studied features of the formation of functional relationships of the respiratory apparatus in young people due to the level of aerobic performance, which shows the ability to generate energy and is the main indicator of the functional state of the respiratory and cardiovascular systems [4, 5]. Morphological specificity of organs and tissues is the main

© Інститут фізіології ім. О.О. Богомольця НАН України, 2026

functional feature of the organization of these systems in humans.

Accordingly, it is advisable to assess the functional state of the respiratory system, considering somatotypological features, which makes it possible to predict the dependence of the development of respiratory diseases in young people with different somatotypes and determine risk groups for the development of pathologies [6].

The literature mainly deals with the morphofunctional features of children of different periods of childhood and adults, while the youth population, which is unstable in the processes of growth and development, remains poorly studied [7, 8].

Modern studies have confirmed the somatotypological characteristics of external breathing indicators in healthy young people. During the study, the characteristics of representatives of different constitutional groups and correlational relationships between spirometric and anthropometric characteristics were revealed [4, 9]. In particular, it was found that functional indicators of external breathing and anthropometric indicators correlated the most in representatives of the thoracic and muscular somatotypes, while in representatives of the abdominal somatotype, there were no such correlations. This indicates that somatotype does not affect growth and development [10].

The lack of a clear understanding of the relationship between the components of the somatotype and the anthropometric characteristics of the morphofunctional indicators of the respiratory system indicates that research aimed at establishing various aspects of human anthropometry and viscerometry of internal organs in different age periods is relevant and practically significant.

Thus, our study aimed to determine the somatotypological characteristics and functional features of respiratory system states and aerobic productivity levels in boys and girls of different somatotypes.

METHODS

Somatotypological affiliation was determined using the Heath-Carter method. Spirography and aerobic performance indicators were used to assess the functional state of the respiratory system. 58 clinically healthy young men and girls aged 19-20 were selected for the study (25 boys and 33 girls). It was also divided into five somatotypological groups: balanced, ectomorphic, endomorphic, endomorphic-mesomorphic and mesomorphic. Group formation was carried out according to the principle of representativeness: each group included at least 5 people of the same calendar and biological age. Determination of the biological age of persons was carried out by the Voitenko method (questionnaire, anthropometry, Stange test, Genchi test, Ozeretsky test) [11].

Given that oxygen consumption rate is limited by pulmonary function, we used spirometry to assess the respiratory system's functional status. Among the indexes we determinated RR (Respiratory Rate), V_E (Minute Ventilation), VC (Vital Capacity), ERV (Expiratory Reserve Volume), t in (Time of Inspiration), t ex (Time of Exspiration), RV (Residual Volume) as well as VO_2 (Oxygen Consumption), VO_2^r (Relative VO_2max), O_2-pulse (Oxygen Pulse), MLV (Maximum Lung Ventilation), ABP/VBP (Arterial/Venous Blood Pressure) and HR (Heart Rate). The main volume and velocity indicators (LV (Lung Volume), FVC_1 (Forced Vital Capacity in 1 sec), and IRV (Inspiratory Reserve Volume)) were evaluated. The level of aerobic productivity and physical capacity was determined using the cycle ergometric test PWC (according to Cartman) and the calculation of maximum oxygen consumption (VO_{max}), both absolute (min^{-1}) and relative ($ml \cdot min^{-1} \cdot kg^{-1}$), which is the "golden standard" for assessing the aerobic capacity of the body. The study of external breathing indicators was conducted using the American Thoracic Society methodology.

The obtained data were processed using the application package "Statistica 6.0". For a preliminary assessment of the normality of the

distribution of data sets, using the Shapiro-Wilk, Fisher criteria and the Kolmogorov-Smirnov agreement criterion, a calculation of variance was carried out, where a qualitative analysis showed that the array of analytical data fully reflects the general population of the sample, and the sample itself is correct. In order to assess the simultaneous influence of gender and somatotype factors on the research indicators of the criteria for assessing the state of the respiratory system, we used a two-factor variance analysis of the obtained values. Then, pairwise comparisons of the indexes of each somatotype group were performed using the Tukey post hoc test. At the same time, the hypothesis (H0) was tested regarding the presence or absence of the influence of factors on changes in the values of the characteristic, which served as an evaluation parameter. If the hypothesis was rejected, a quantitative assessment of the influence of the factor on the studied indicator was carried out, and confidence intervals were constructed to obtain the corresponding characteristics. The critical level of significance (P) when testing statistical hypotheses was taken as equal to 0.05.

RESULTS AND DISCUSSION

The analysis of the functional state of the cardiovascular and respiratory systems showed that the average values of functional and spirometric indicators of all examinees were within the physiological norm (Table 1).

At the same time, several statistically significant differences determined by gender and constitutional characteristics of the subjects were revealed. It was established that representatives of the endomorphic somatotype are characterized lower indicators of external respiration and aerobic productivity compared to other groups. It is known that individuals with a predominance of the fat component of the body have a smaller functional reserve of the respiratory system, which can increase their susceptibility to respiratory diseases. It is known that individuals of the ectomorphic somatotype have a specific architecture of the chest, which contributes to a high VC relative to body weight, but their respiratory musculature is often inferior to that of mesomorphs. Instead, the endomorphic type often shows signs of isoventilatory adjustment of breathing at rest with lower inspiratory and expiratory reserve volumes, which limits their adaptation to intense physical exertion [5, 12].

In girls in our study, intergroup variability of speed indicators was revealed: representatives of the ectomorphic type had significantly lower values of forced expiratory volume per second (FEV1) than girls of the mesomorphic somatotype. On the other hand, statistically significant differences in this indicator depending on the body type were not recorded in the young men.

The comparative analysis revealed pronounced sexual dimorphism in most parameters, in particular, young men of mesomorphic, ectomorphic and ecto-mesomorphic somatotypes showed significantly higher values of VC compared to girls of the respective groups. The rate of one-second forced exhalation was significantly higher in young men of all somatotypes, which confirms the gender difference in the power of respiratory muscles. However, young men of mesomorphic and ectomorphic types had a larger volume of residual air compared to girls. In the group of ecto-mesomorphs, the gender difference according to this indicator was levelled. At the same time, no statistically significant differences were found between mesomorph girls and boys. To assess the simultaneous influence of gender and somatotype on the respiratory system indicators, a two-way ANOVA was performed. The results, detailed in the tables, highlight that somatotype was a dominant factor ($P < 0.05$) for VC ($F = 206.30$), IRV ($F = 201.88$), ERV ($F = 206.30$), FVC_1 ($F = 201.88$), and V_E ($F = 206.30$). Furthermore, the interaction effect (Somatotype × Gender) was statistically significant ($F = 264.41$; $P < 0.05$), accounting for 13.66% to 24.35% of the variance in volumetric characteristics (IRV, ERV, VE). This confirms that sexual dimorphism in respiratory function is specifically manifested

Table 1. Dynamics of external breathing indicators depending on somatotype and gender (M ± m)

Index	Somatotype									
	balanced		ectomorphic		endomorphic		endomorphic-mesomorphic		mesomorphic	
	male (n=8)	female (n=5)	male (n=5)	female (n=5)	male (n=7)	female (n=5)	male (n=6)	female (n=5)	male (n=7)	female (n=5)
Respiratory rate	11.8±0.8	12.5±0.6	11.6±0.5	12.2±0.4	11.5±0.9	12.3±0.7	10.3±0.6	11.6±0.5	9.9±0.5*	10.6±0.4*
lung volume, Ml	701.2±47.8	595.2±42.1	719.4±46.7	605.4±40.3	694.1±27.2	582.7±23.4	782.6±21.9	658.4±19.2	723.3±38.5	612.5±34.6
Minute ventilation, min^{-1}	8.3±0.7	8.4±0.5	8.3±0.6	7.4±0.5	7.9±0.6	7.1±0.6	8.1±0.6	7.4±0.4	7.2±0.8	6.5±0.6
Vital capacity, ml	3985.4±90.7	3240.5±82.4	3350.6±80.0	2780.2±74.6	2869.5±103.3*	2385.4±84.2*	3683.9±98.9	3110.7±91.5	3873.8±104.6	3302.4±98.3
Inpiratory reserve volume, ml	1847.1±90.7	1502.4±81.2	1472.2±46.7	1215.8±42.1	1195.3±61.6*	1010.2±54.5*	1549.1±49.5	1320.5±44.8	1689.7±63.5	1445.6±58.2
Expiratory reserve volume, ml	1437.1±59.7	1142.9±52.3	1159.0±43.3	959.0±39.4	980.1±46.2*	792.5±41.6	1352.2±43.9	1131.8±40.2	1460.0±58.9	1244.3±51.1
Time of inspiration, s	1.1±0.03	1.1±0.03	1.1±0.03	1.1±0.03	1.3±0.1	1.3±0.1	1.3±0.04	1.3±0.04	1.2±0.05	1.1±0.05
Time of exspiration, s	1.7±0.07	1.7±0.07	1.6±0.05	1.5±0.05	1.6±0.08	1.5±0.08	1.9±0.08	1.9±0.08	1.6±0.07	1.4±0.06
Forced vital capacity in 1 s, ml	3901.1±62.1	3185.4±58.7	3127.8±106.7	2620.3±98.2	2610.0±115.6*	2195.4±102.3	3389.6±109.1	2940.8±101.4	3779.7±105.2	3225.5±99.6
Tiffno-votchal index, ml/s	3037.5±121.9	610.2±110.4	2542.3±101.7	2210.5±94.3	2181.7±63.9	1895.4±58.2	2954.8±115.4	2580.3±108.1	3049.8±99.8	2690.4±92.5
Residual volume, %	88.1±1.5	86.9±1.3	87.2±1.3	84.9±1.2	89.1±1.1	89.0±1.1	87.9±1.3	87.8±1.4	87.9±1.5	84.2±1.3
Oxygen consumption, ml/min	286.6±7.2	242.3±6.5	295.0±12.7	254.1±10.8	230.0±8.5*	198.2±7.6	316.5±9.9*	278.5±9.1	289.0±8.2	248.6±7.4
Relative oxygen consumption, $ml \cdot min^{-1} \cdot kg^{-1}$	4.2±0.1	4.2±0.1	4.1±0.1	3.9±01	3.8±0.2	3.8±0.2	4.1±0.2	4.2±0.2	4.1±0.1	4.0±0.1
Oxygen pulse, ml	34.5±1.1	34.8±1.0	35.5±0.5	35.1±0.5	29.1±1.0*	30.4±1.0*	39.1±1.0*	39.1±1.0*	36.6±0.7	35.8±0.7
Maximum lung ventilation, l	69.9±3.7	55.4±3.1	64.6±3.5	51.2±3.0	66.1±7.6	52.5±6.1	67.1±3.6	54.8±2.9	65.2±3.0	53.7±2.5

Notes: *P < 0.05 versus other somatotype groups.

depending on the individual's constitutional type.

The analysis of spirometric indicators confirmed that the condition of the respiratory system of the examined persons as a whole corresponds to the physiological norm. However, a clear dependence of the dynamic parameters of breathing on the constitutional type has been established. In particular, representatives of the mesomorphic somatotype had the lowest respiratory rate (RR), which indicates Isoventilatory adjustment. Instead, the endomorphic-mesomorphic group recorded the highest absolute oxygen consumption (VO_2) and oxygen utilization coefficient (O_2-pulse).

The lowest values of vital capacity lungs (VC), inspiratory reserve volume (IRV), FEV_1 and the Tiffno-Votchal index were found in representatives of the endomorphic somatotype. The obtained data correlate with the results of modern literary sources, which indicate a lower level of functional reserves of the respiratory system in persons with a predominance of the fat component of body weight [13].

In a comparative analysis of the cardiovascular system, it was found that individuals with an ectomorphic somatotype probably have lower systolic and diastolic blood pressure indicators than representatives of other groups (Table 2). The latest studies indicate that, within one somatotype, girls have lower absolute values of cardiac output and minute ventilation. This is due to hormonal differences and morphological variations, such as a smaller left ventricular volume and alveolar surface area in the lungs [3, 14]. It is known that ectomorphs are prone to parasympathetic dominance, manifested by lower blood pressure and bradycardia at rest. In contrast, endomorphs are at higher risk of early arterial hypertension, as confirmed by higher ABP indicators in the results of their own research. Mesomorphs demonstrate adequacy rather than a mandatory resting advantage, but have a higher functional reserve (which is confirmed by higher VC and FVC_1 scores) [16, 17].

Endomorphic somatotype individuals remain a risk group due to reduced reserve capabilities

Table 2. Indicators of the functional state of the cardiovascular system (M±m)

Index	Somatotype									
	balanced		ectomorphic		endomorphic		endomorphic-mesomorphic		mesomorphic	
	male (n=8)	female (n=5)	male (n=5)	female (n=5)	male (n=7)	female (n=5)	male (n=6)	female (n=5)	male (n=7)	female (n=5)
Arterial pressure, mmHg	118.3±0.9	111.5±0.8	113.9±2.0*	107.4±1.8*	122.4±2.3	117.8±2.0	118.7±1.1	113.2±1.0	118.8±0.9	114.1±0.8
Venous pressure, mmHg	76.2±0.7	73.4±0.6	70.9±1.4*	67.5±1.2*	71.7±1.3	69.4±1.5	77.6±1.1	74.3±1.2	73.8±1.3	71.2±1.4
Heart rate, beats/min	69.5±1.4	74.2±1.2	66.6±1.7	72.1±1.5	69.5±1.2	75.4±1.1	68.3±1.5	73.8±1.3	67.3±1.0	72.3±1.2

Note: *P< 0.05 versus other somatotype groups.

[18]. In contrast, mesomorphs show an increase in LV that reflects robust respiratory musculature, a trend confirmed by the high significance of the somatotype factor (F = 206.30 for VC). Gender differences in the structure of forced expiratory volume were also revealed: at the level of VC, statistically significant differences were observed between boys and girls within identical somatotypes (Table 1).

Modern research suggests that the somatotype is a genetically determined marker that determines not only the constitutional features of the physique, but also the development of visceral systems. Also, studies indicate that belonging to the mesomorphic somatotype is closely correlated with high aerobic and anaerobic power. In individuals of the mesomorphic type, an optimal ratio of muscle mass and lung volume is observed, which provides high PWC_{170} and VO_2max rates [2, 7]. An aerobic capacity study found that the level of maximal oxygen intake in all groups examined exceeded the "safe level of somatic health". According to the G.L. Apanasenko criteria, for men, this threshold is 42 $ml \cdot min^{-1} \cdot kg^{-1}$ (Table 3).

The results confirm a direct relationship between anthropometric performance and physical performance. In particular, the highest relative MSC values ($ml \cdot min^{-1} \cdot kg^{-1}$) were recorded in individuals with asthenic body structure (ectomorphs). The lowest values were observed in the overweight group. The significance of relative indexes PWC170 and VO2 max depends on the somatotype.

Despite the high general level of functioning of the respiratory system, the group of endomorphs needs special attention. Taking into account the specifics of their working capacity (absolute indicator - 28.5%, relative - 13.8), this category of people has a higher risk of developing prepathological conditions of the cardiovascular and respiratory systems in the early stages. The identified somatotypological features dictate the need for an individual approach to health monitoring and the development of preventive measures. especially for representatives of the endomorphic constitutional type.

Table 3. Aerobic energy supply profile in different constitutional groups (M ± m)

Index	Somatotype									
	balanced		ectomorphic		endomorphic		endomorphic-mesomorphic		mesomorphic	
	male (n=8)	female (n=5)	male (n=5)	female (n=5)	male (n=7)	female (n=5)	male (n=6)	female (n=5)	male (n=7)	female (n=5)
Physical working capacity abs., $kg \cdot m \cdot min^{-1}$	1107.4±33.1	885.2±30.4	1204.2±56.3	965.4±48.1	775.5±26.5*	620.3±22.4*	1331.8±45.1	1065.2±41.3	1331.8±45.1	1108.1±45.6
Physical working capacity rel., $kg \cdot m^{-1} \cdot min^{-1}$	16.5±0.30	14.8±0.2	16.9±0.20	15.8±0.2	13.2±0.40*	11.5±0.3*	17.0±0.40	15.5±0.3	17.0±0.40	16.2±0.4
Maximum oxygen consumption abs., ml/min^{-1}	3140.6±42.8	2680.2±38.5	3307.6±96.1	2840.4±82.3	2560.6±45.0*	2185.2±40.1*	3522.8±76.6	3105.4±70.2	3527.2±76.6	3190.5±75.4
Maximum oxygen consumption rel., $ml \cdot min^{-1} \cdot kg^{-1}$	46.2±0.50	42.7±0.4	45.3±0.70	44.1±0.6	44.2±0.70*	39.2±0.7*	43.2±0.60	43.7±0.6	47.4±0.60	45.2±0.6

Notes: *P< 0.05 versus other somatotype groups.

CONCLUSIONS

1. The constitutional factor enhances the sexual dimorphism of most spirometric parameters. The mesomorphic type of body structure is associated with higher volumetric breathing rates and isoventilatory adjustment of function (lowest respiratory rate).

2. The ectomorphic somatotype is characterized by lower blood pressure and high relative aerobic power.

3. Individuals of the endomorphic somatotype remain in a risk group due to reduced reserve capabilities. In contrast, mesomorphs show an increase in LV that reflects robust respiratory musculature, a trend confirmed by the high significance of the somatotype factor.

4. Detected that in representatives of the endomorphic somatotype, some indicators of external respiration and the level of aerobic performance are lower. compared to representatives of other somatotypological groups.

5. It is shown that the greatest influence of the factor of somatotype is with a probability of 95% for the indexes of vital capacity, exspiratory reserve volume, forced vital capacity in 1 s, minute ventilation, relative indexes of physical working capacity at 170 bpm and maximal oxygen consumption. At the same time, the level of influence of the gender factor on spirometry indicators was from 24.35% to 13.66%.

The study of correlations between anthroposomatotypological parameters and functional indicators will make it possible to more accurately differentiate the boundaries of the physiological norm for adolescents of different constitutional groups.

The authors of this study confirm that the research and publication of the results were not associated with any conflicts regarding commercial or financial relations, relations with organizations and/or individuals who may have been related to the study, and interrelations of co-authors of the article.

Б.О. Лісова, О.О. Городецька, Ю.В. Кириченко

СОМАТОТИПОЛОГІЧНІ ОСОБЛИВОСТІ ФУНКЦІОНАЛЬНОГО СТАНУ ДИХАЛЬНОЇ СИСТЕМИ ТА АЕРОБНОЇ ПРОДУКТИВНОСТІ МОЛОДІ

Вінницький національний медичний університет ім. М.І. Пирогова; e-mail: danotchka@gmail.com

Наразі особливої уваги потребує вивчення функціонального стану дихальної та серцево-судинної систем молоді, оскільки цей віковий період є критичним для формування адаптаційних резервів організму. Незважаючи на наявність досліджень морфофункціональних особливостей, зв'язок між соматотипом та показниками аеробної продуктивності у юнацькому віці залишається недостатньо з'ясованим. Метою нашої роботи було визначення соматотипологічних характеристик, функціональних особливостей респіраторної системи та рівня аеробної продуктивності у 58 здорових юнаків і дівчат різних конституційних груп. Соматотипування проводили за методом Хіт-Картера з розподілом на п'ять груп: збалансований, ектоморфний, ендоморфний, ендоморфно-мезоморфний та мезоморфний типи. Функціональний стан оцінювали методами спірографії (життєва ємність легень – ЖЄЛ, об'єм форсованого видиху за 1 с, форсована життєва ємність легень) та велоергометрії (працездатність, максимальне споживання кисню). Встановлено, що середні значення показників респіраторної та серцево-судинної систем обстежених знаходяться в межах фізіологічної норми, проте мають чітку соматотипологічну залежність. Представники мезоморфного типу демонструють найвищу економізацію дихання (нижча частота дихання) та високі об'ємні показники. Ектоморфний соматотип асоціюється з вірогідно нижчим артеріальним тиском та високою відносною аеробною потужністю. Найменші значення ЖЄЛ, резервного об'єму вдиху та індексу Тіффно-Вотчала, а також фізичної працездатності зафіксовані у представників ендоморфного соматотипу. Виявлено виражений статевий диморфізм: у юнаків усіх груп переважали порівняно з дівчатами потужність дихальних м'язів та об'ємні характеристик легень. Таким чином, було встановлено, що конституційний чинник суттєво модифікує функціональні параметри організму. Особи з ендоморфним соматотипом становлять групу ризику через знижені резервні можливості респіраторної системи та нижчу аеробну продуктивність. Отримані результати обґрунтовують необхідність впровадження індивідуалізованих нормативів для моніторингу здоров'я молоді з урахуванням їхнього соматотипу.

Ключові слова: показники зовнішнього дихання; соматотип; юнацький вік; спірометрія; максимальне споживання кисню.

REFERENCES

1. Banakh V, Iedynak G, Sovtisik D, Galamanzhuk L, Bodnar A, Blavt O, et al. Physiological characteristics of young people in the absence of mandatory physical activity required at the university. Phys Educ Theor Methodol. 2023; 23(2): 253-62. doi.org/10.17309/tmfv.2023.2.14.
2. Falcioni L, Guidetti L, Baldari C, Gallotta MC, Meucci M. Oxygen uptake efficiency slope in healthy normal weight young males: an applicable framework for calculation and interpretation. Peer J. 2022;10: e13709. doi: 10.7717/peerj.13709.
3. Gutnik B, Zuoza A, Zuozienė I, Alekrinskis A, Nash D, Scherbina SI. Body physique and dominant somatotype in relation to physical performance indicators in young adults. J Phys Educ Sport. 2015;21(3):1345-52. doi: 10.1016/j.medici.2015.07.003.
4. Held S, Behringer M, Donath L. Low intensity rowing with blood flow restriction over 5 weeks increases VO_2max in elite rowers: A randomized controlled trial. J Sci Med Sport. 2020;23(3):304-8. doi: 10.1016/j.jsams.2019.10.002.
5. Lipowicz A, Pol A, Świerczyńska K, Knapik A, Nowak Z, Myśliwiec A, et al. Cardiorespiratory fitness of healthy Polish men and women with various somatotypes. BMC Cardiovasc Dis. 2025;26: 58. doi: 10.1186/s12872-025-05436-7.
6. Peric R, Mercado-Ruiz JP, Meucci M, Kim H, Amaro-Gahete FJ, Ramos-Jimenez A, et al. Comparative contributions of oxygen uptake efficiency and maximal oxygen uptake to fat oxidation metrics in healthy male adults. Sport Med Open. 2025;11: 120. doi: 10.1186/s40798-025-00889-8.
7. Miroshnichenko VM. Characteristics of aerobic potentials in men of the first mature age with different somatotypes. Phys Cult Sport Health Nat. 2017;3(22):587-91.
8. Sarafynyuk LF, Sarafynyuk PV. Relationship of spirometric and echocardiographic parameters with total and longitudinal body sizes. Rep Morphol. 2015;21(1):165-8.
9. Sáez-Olivares S, Pino-Zúñiga J, Olivares-Gálvez M, Cancino-López J. Maximal fat oxidation by heart rate variability in physically active subjects. Apunts Educ Fís Esports. 2019;138:111-22. doi: 10.5672/apunts.2014-0983.es.(2019/4).138.09.
10. Kyrychenko YV, Sarafyniuk LA, Khapitska OP, Dus SV, Yakusheva YI. Peculiarities of correlations between spirometric and anthropometric indicators in practically healthy young women of mesomorphic somatotype. Rep Morphol. 2023;29(3):58-66. doi: 10.31393/morphology-journal-2023-29(3)-09.
11. Leont'ieva ZR, Dutka RY. Biological age and aging rates of students. Bukovyn Med Visn. 2016;20(3):107-9.
12. Nesterova SY, Sulyma AS, Boiko MO. Determination and assessment of the level of physical health of youth 18-20 years old with different somatotype. Phys Educ Sport Health Cult Mod Soc. 2019;2:35-40.
13. Petrik KY, Kritschfalushii OP. Adaptive capabilities of middle school-aged girls depending on the ratio of adipose and muscle tissue. Wiad Lek. 2022;75(4 pt 2):944-8.
14. Buttar KK, Saboo N, Kacker S. A review: Maximal oxygen uptake (VO_2 max) and its estimation methods. IJPESH. 2019;6:24-32.
15. Kruk M, Liashevych A, Chernukha I, Kruk A, Levchuk L. Functional state of cardiorespiratory system of students' body who are engaged in physical culture and sports. Sci J Nat Pedagog Dragomanov Univ. Ser 15. 2020; 3(123): 93-7. doi: 10.31392/NPU-nc.series15.2020.3(123).18.
16. Miroshnichenko V, Salnykova S, Brezdeniuk O, Nesterova S, Sulyma A, Onyshchuk V, et al. The maximum oxygen consumption and body structure component of women at the first period of mature age with a different somatotypes. Pedag Psychol Med-Biol Probl Phys Train Sport. 2018; 22(6): 306-12. doi: 10.15561/18189172.2018.0605.
17. Stewart A, Marfell-Jones MJ. International standards for anthropometric assessment. New Zealand: ISAK; 2011.
18. Bordoni B, Escher AR. Obesity and the importance of breathing. Cureus. 2025;17(1):e77431. doi: 10.7759/cureus.77431.

Received 13.04.2026