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Aerobic Potential And Adaptation Of 11-15- Year Olds To The Environment

Elena N. Khorolskaya, Tatyana A. Pogrebnyak*, Irina V. Sagalaeva, Ekaterina V. Zubareva, Daria N. Maslova, Ekaterina S. Artischeva

Belgorod State University, 85, Pobedy St., Belgorod, 308015, Russia

email*: Pogrebnyak@bsu.edu.ru

Abstract

Background: This study was performed to evaluate the aerobic potential of adolescents aged 11-15 years on physical and physiometric parameters of physical growth, assessment of the musculoskeletal system and respiratory system, the vital capacity of lungs (VLC) using Shtange and Genchi functional tests.

Materials and Methods: The study was conducted based on Municipal Budget Training Institute at "High School" in Belgorod. In this experiment, 120 boys and girls were classified into three age groups included 11 years old, 12-13 years old, and 14-15 years old. All students were healthy at the time of the study with health groups I or II. All students and parents were introduced to the purpose and methods of physiological study. Assessment of the level of achievement of physical growth and physical health of students was performed for both age and gender groups of adolescents and at the individual level. Students' aerobic potential was assessed using indicators and performance tests. Body mass, body length, and chest circumference were measured using somatometric methods. The integral Penier index was calculated.

Results: The results of this study showed that boys had a higher rate of HSI compared to girls. Among boys, the highest HSI was in the age group of 12 to 13 years (48.0±2.24), followed by 14 to 15 years (47.3±2.35) and 11 years (42.6±2.20). The highest value of this trait was in girls in the age group of 14 to 15 years (40.6±2.21) and the lowest was related to the age group of 11 years (39.2±1.43) ($P<0.01$). The experimental results showed that the aerobic potential and level of physical health of students during their development were severe, and the gender-age difference in the aerobic capacity of the respiratory system that affected the body's energy function and its adaptation processes were identified. There were no significant differences in the values of VLC and LI between the boys and girls at the same age.

Discussion: Low levels of physical growth, poor growth of muscles and limbs in most adolescents with inactivity, low levels of physical activity. Low HSI values in adolescents are due to excess body weight. A wide range of individual data points to the not simultaneous entry of students of the same age into the period of puberty. This pattern of physical development is genetically determined and related to the heterochronous processes. Another significant factor is the lack of proper level of motor activity of schoolchildren during the day. The results showed that boys at the age of 14 to 15 years had the most severe and heterogeneous stages of development of various organs and systems of the body, which indicated the need for high energy consumption and thus reduced adaptability.

Keywords: Aerobic potential, Muscle apparatus, Physical development, Physical performance, Respiratory system, Maximum oxygen consumption

Potentiel aérobie et adaptation des 11-15 ans à l'environnement

Résumé

Contexte: Cette étude a été réalisée pour évaluer le potentiel aérobie d'adolescents âgés de 11 à 15 ans sur les paramètres physiques et physiométriques de la croissance physique, l'évaluation du système musculo-squelettique et respiratoire, la capacité vitale des poumons (VLC) à l'aide des tests fonctionnels Shtange et Genchi .

Matériels et méthodes: L'étude a été menée sur la base de l'Institut municipal de formation budgétaire au « Lycée » de Belgorod. Dans cette expérience, 120 garçons et filles ont été classés en trois groupes d'âge : 11 ans, 12-13 ans et 14-15 ans. Tous les étudiants étaient en bonne santé au moment de l'étude avec les groupes de santé I ou II. Tous les élèves et les parents ont été initiés au but et aux méthodes de l'étude physiologique. L'évaluation du niveau de croissance physique et de santé physique des élèves a été réalisée pour les groupes d'âge et de sexe des adolescents et au niveau individuel. Le potentiel aérobie des élèves a été évalué à l'aide d'indicateurs et de tests de performance. La masse corporelle, la longueur du corps et le tour de poitrine ont été mesurés à l'aide de méthodes somatométriques. L'indice de Penier intégral a été calculé.

Résultats: Les résultats de cette étude ont montré que les garçons avaient un taux de HSI plus élevé que les filles. Chez les garçons, le HSI le plus élevé était dans le groupe d'âge de 12 à 13 ans (48,0 ± 2,24), suivi de 14 à 15 ans (47,3 ± 2,35) et 11 ans (42,6 ± 2,20). La valeur la plus élevée de ce trait était chez les filles dans le groupe d'âge de 14 à 15 ans (40,6 ± 2,21) et la plus faible était liée au groupe d'âge de 11 ans (39,2 ± 1,43) ($P < 0,01$). Les résultats expérimentaux ont montré que le potentiel aérobie et le niveau de santé physique des élèves au cours de leur développement étaient sévères, et la différence entre les sexes et l'âge dans la capacité aérobie du système respiratoire qui affectait la fonction énergétique du corps et ses processus d'adaptation a été identifiée. Il n'y avait pas de différences significatives dans les valeurs de VLC et LI entre les garçons et les filles du même âge.

Discussion: Faibles niveaux de croissance physique, faible croissance des muscles et des membres chez la plupart des adolescents inactifs, faibles niveaux d'activité physique. Les valeurs HSI faibles chez les adolescents sont dues à un excès de poids corporel. Un large éventail de données individuelles indique l'entrée non simultanée des élèves du même âge dans la période de la puberté. Ce modèle de développement physique est déterminé génétiquement et lié aux processus hétérochrones. Un autre facteur important est le manque d'activité motrice adéquate des écoliers pendant la journée. Les résultats ont montré que les garçons âgés de 14 à 15 ans présentaient les stades de développement les plus sévères et hétérogènes de divers organes et systèmes du corps, ce qui indiquait la nécessité d'une consommation d'énergie élevée et donc une capacité d'adaptation réduite.

Mots clés: Potentiel aérobie, Appareil musculaire, Développement physique, Performance physique, Système respiratoire, Consommation maximale d'oxygène

1. Introduction

With the growth of physiology in sport and the emphasis on the benefits of physical activity in children and adolescents [1, 2], it is important to understand the physiological aspects of physical activity in them [3]. On the other hand, ethical and methodological factors in research limit access to information resulting from the effects of exercise and physical activity in children and adolescents [4, 5, 6]. But so far, researchers have used a variety of methods to study children and emphasized that children should not be considered as young adults because each of them is unique and has age-appropriate responses and behaviors that are unique at each stage of development [7, 8], and these differences to the level of biological maturity [9, 10]. Before puberty, children have lower cardiac output [11] and lower glycolytic activity [12], but during puberty, the secretion of hormones such as somatotropin [13], insulin-like growth factor [14] and steroids [15] into the bloodstream increases, increasing lean body mass [16], and fat mass [17]. They become sex-dependent, changes in body composition, and the development of physiological [18] and functional capacities [19]. Therefore, awareness of

physiological changes in the period before, during and after puberty is very important for children to determine the type, volume and intensity of activity [19, 20].

The aerobic capabilities of a growing organism at any stage of physical development determine its rate and level of somatic health, the intensity of motor activity during the day and the ability to adapt to current and dosed physical and mental loads [21, 22]. A high level of catabolism processes and energy consumption in the growing body provides functional induction of excess metabolism determining the growth rate and the ability of the biosystem to adapt [23, 24]. Aerobic metabolism, also known as oxidative metabolism [25], is directly dependent on the mitochondrial capacity of active tissues (skeletal muscle) [26], the Krebs cycle (TCA), and the electron transfer chain, so factors that increase tissue oxidative capacity [27] include: Slow-twitch fibers (type I) in muscle [28], 2) high mitochondrial density in the sarcoplasm [29], 3) increased concentration and catabolic activity of oxidative enzymes [30], and 4) increased blood vessel density in tissues [31]. Research shows that a high percentage of type I fiber and oxidative enzymes of the Krebs cycle (isocitrate dehydrogenase, fumarase, and malate dehydrogenase) are higher in children than in adults [32, 33, 34].

The results of studies showed that children have a high rate of oxidative phosphorylation during strenuous activity compared to adults, which is consistent with the high density of arteries and mitochondria in children's muscles [35, 36]. Researchers showed that pre-adolescent children in activities below the absolute maximum have a significantly lower respiratory rate (RER) ratio [37, 38, 39] compared to adults, and also have a higher metabolic rate in children. Part of this difference is due to the greater secretion of growth hormone (GH) at this age [40]. The source of energy for long-term activities in children than adults is that this age group relies on fat oxidation [41], the release of free fatty acids (FFA) [42], glycerol [43], and growth hormone [44]. If children consume glucose-rich solution at the beginning of the long-term activity [45], their plasma glucose levels are higher than in adults during activity, due to low insulin sensitivity during puberty [46].

Arshavsky considered growth as a process of excessive anabolism, which is induced by functional activity, i.e. catabolism, in which the amount of internal and free energy increases [47, 48]. Therefore, the higher is the body's ability to adapt, the higher is its energy potential. Flexible connection of the organism with the environment determines the interaction of two components of any biosystem - neuroendocrine regulation of metabolism and the energy substrate itself [49, 50]. These components define the essence of development and the basis of adaptive behavior [47, 49, 51].

The highest limit of the body's available aerobic energy supply (energy reserve) is provided by its ability to absorb oxygen: the greater is this ability, the higher is the level of somatic health [49, 52].

The use of unified testing samples with dosed physical load (step-test), allows by means of an indirect method to calculate the maximum oxygen consumption (MOC) [47] and on its basis to assess the level of somatic health and physical performance of the body [53, 54]. The purpose of work is to evaluate the aerobic potential of the respiratory system taking into account the level of physical development of adolescents and maximum oxygen consumption (MOC).

2. Materials and Methods

The study was conducted based on the MBEI (Municipal Budget Educational Institute) "High School No. 42" in Belgorod. In this study, 120 boys and girls in three age groups of 11 years old, 12-13 years old and 14-15 years old, which were in physical health at the time of the study, were used. At the time of the study, they were in good physical health. The participants in the experiment were in group I or II health and participated in the study voluntarily, and the students and their parents were already familiar with the purpose and methods of the physiological study [55]. Students were grouped both in terms of age group and adolescent gender and in terms of individual level to assess the level of achievement of physical growth and physical health.

The aerobic potential of 11-15-year-old schoolchildren was evaluated using the method of indices and functional tests [47, 56]. These methods allow us to determine the state of physiological systems based on the measurement of several indicators. Using the methods of somatometry, the mass (kg) and body length (cm), chest circumference (CC, cm) were determined in schoolchildren, based on which the integral Penier index (conv.units) was calculated [53, 54, 57]. The methods of physiometry were used in the research. Thus, with the help of dynamometry using a manual dynamometer, the strength of the fingers of the right and left hands (HSr and HSl, kgs) was determined [54, 56]. Based on the data obtained, the index of hand strength (HSI, %) was calculated as the ratio of the strength of both hands to body weight. With the help of spirometry, using a dry spirometer, VLC (l) was determined and the life index (LI, ml/kg) was calculated [47]. The average age norms of VLC are 2.2 and 2.0 l for boys and girls aged 11 years old; 2.4 and 2.2 l for 12-13 years old; 3.2 and 2.7 l for 14-15 years old. The average age norms of LI for boys aged 11-15 years old are 64-65 ml, and for girls aged 11 years - 61 ml, for 12-13 years olds -59 ml, for 14-15 years olds – 57 ml, respectively [49, 52, 54].

The functional capabilities of the respiratory system were evaluated using a Genchi test (breath retention on inspiration) and a Stange test (breath retention on exhalation). The indicators of the Stange test are normally in boys and girls of 11 years old at 51 s and 44 s, in 12-13 years old at 61 s and 49 s, and 14-15 years old at 66 s and 57 s, respectively. Normally, the Genchi test values were 24 s and 20 s for boys and girls of 11 years old, 23 s and 20 s for 12-13 years old, and 26 s and 25 s for 14-15 years old, respectively [53, 54]. This test is performed in a sitting position and the subject should take a deep breath and hold the breath as much as possible. The duration of respiratory arrest is counted with a stopwatch. The stopwatch stops at the moment of exhalation. In healthy but untrained individuals, the duration of breathing is 40 to 60 seconds in men and 30 to 40 seconds in women. In male athletes, this time is 60 to 120 seconds, and in female athletes, it is a maximum of 40 to 95 seconds.

Based on the results of the step test, the individual aerobic potential for each student and the average values for the age groups of boys and girls were calculated [24, 52, 53]. The obtained data were statistically analyzed using descriptive statistics software "Statistica-10" at the level of 5%. The results of the Kolmogorov-Smirnov test showed that the data had a normal distribution, so one-way analysis of variance and paired t-test were used to analyze them.

3. Results

At the first stage of the research, the analysis of physical development indicators that characterize the level of development of the muscle apparatus of a growing organism was carried out. The values of the Penier index are calculated according to individual parameters of somatometry. The analysis of its values showed that a weak body type and weak development of the muscular apparatus is typical for 70% of girls aged 11 and 14-15 years old, and 50% of boys aged 11-15 years old. The average body type was found in 20% of girls aged 11-15 years old above average in other schoolgirls of all age groups. A good body type was found in 30% of boys aged 11-13 years old, strong only in 20% of boys aged 14-15 years old.

The established average and absolute values of the flexor muscle strength of the fingers of both hands and the relative values of HSI in boys and girls are presented in Table 1.

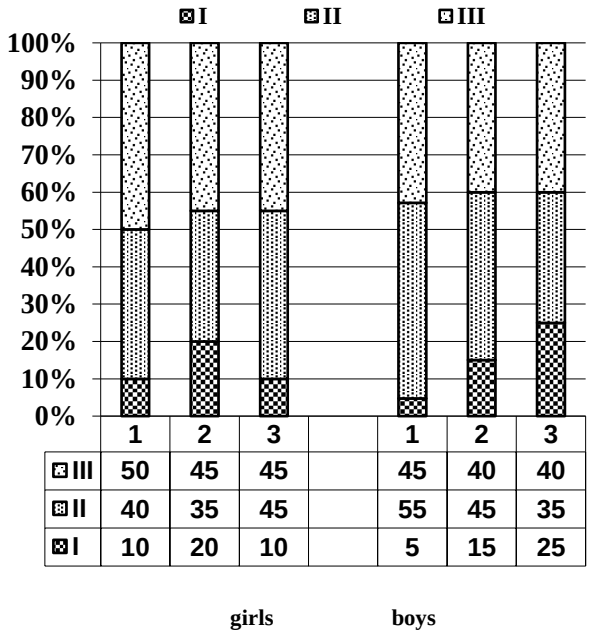
Table 1. Absolute and relative indicators of dynamometry in schoolchildren

Indicators, un.	Boys	Girls
	M±m,	M±m,
11 years old	n =20	n = 20
HS right, kgs	18.0±1.40	16.0±1.20
HS left, kgs	17.6±1.12*	14.2±1.07
HSI, %	42.6±2.20	39.2±1.43
12-13 years old	n = 20	n = 20
HS right, kgs	22.4±1.33	19.6±1.12
HS left, kgs	20.5±1.27	17.4±1.28
HSI, %	48.0±2.24*	40.6±3.36
14-15 years old	n = 20	n =20
HS right, kgs	29.8±1.88*	24.5±1.68
HS left, kgs	27.4±2.42	22.2±2.24
HSI, %	47.3±2.35*	40.6±2.21

Note: * p≤0.05 in comparison between boys and girls of the same age.

The HSI percentage of boys was higher in all three age groups than girls. Thus, the rate of HSI in boys 11, 12 to 13, and 14 to 15 years old was 42.6±2.20, 48.0±2.24, and 47.3±2.35%, respectively, and this rate in girls was 39.2±1.43, 40.6±3.36, and 40.6±2.21% was calculated. The highest HSI was obtained in the age range of 12 to 13 in both sexes. A comparative analysis with age norms of the average values of the muscle strength of the flexors of the fingers of both hands showed that in boys and girls of 11 and 12-13 years old, their average values are marked within the lower limits of the norm. The average values of muscle strength of the fingers of the right and left hands in 14-15-year-old boys were reduced against the age norm. Taking into account the individual values of HSI, students were assigned to different levels of physical development and, accordingly, somatic health (Figure 1). Thus, according to the relative values of HSI, a low

level of physical development was detected in 80% of 11-15-year-old girls, 80% of 11-year-olds, and 40% of boys aged 13-15 years old (Figure 1).



	1	2	3		1	2	3
III	50	45	45		45	40	40
II	40	35	45		55	45	35
I	10	20	10		5	15	25

Figure 1. The level of physical (somatic) development and health of schoolchildren according to individual values of HSI: I – high, II – medium, III – low levels.

According to individual relative values of HSI, a low level of physical development and somatic health was found in 50% of 11-year-old and 45% of 12-15-year-old girls; in 45% of 11-year-old and 40% of 12-13-year-old boys (Figure 2). The average level of development was observed, respectively, in 40% of 11 year-old girls and 55% boys; 35% of 12-13 year-old girls and 45% boys; 45% of 14-15 year-old girls and 35% boys.

Table 2 shows the average values of VLC and LI found in schoolchildren, which are characterized by a wide range of individual values. The values of VLC in all age groups of boys and girls were reduced against the age norms equal for boys and girls aged 11 years 2, 5, and 2.3 l, in 12-13 year-olds 2.6 and 2.7 l, in 14-15 years-olds 3.6 and 3.2 l, respectively. According to these data, all students have reduced adaptive capabilities.

Table 2. Absolute and relative indicators of dynamometry in schoolchildren

Indicators, un.	**Boys**	**Girls**
	M±m, min- max	**M±m, min-max**
11 years old	n =20	n = 20
VLC, l	2.0±0.25 1.8-2.4	1.9±0.27 1.7-2.3

LI, ml/kg	48.5±2.85	46.0±2.60
	34.1-65.0	32.8-56.5
12-13 years old	n = 20	n = 20
VLC, l	2.3±0.15	2.2±0.17
	1.8-3.4	1.9-3.1
LI, ml/kg	46.8±2.11	48.5±2.91
	36.0-65.0	34.0-67.0
14-15 years old	n = 20	n =20
VLC, l	2.9±0.28	2.7±0.37
	2.0-3.1	2.0-3.0
LI, ml/kg	46.5±1.64	44.0±2.05
	40.5-61.5	39.8-58.0

There were no significant differences in the values of VLC and LI between the boys and girls of the same age. Indicators of functional tests with breath retention on inspiration (Stange test) revealed weak development of the external respiratory system with low functional capabilities only in 14-15-year-old girls. The percentage of girls with average, high, and excellent health prevailed in the younger age groups (Figure 2).

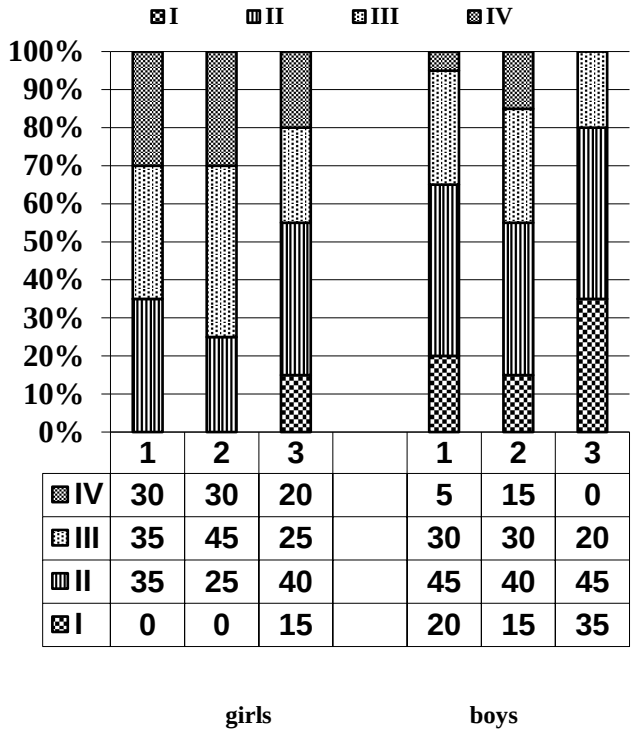
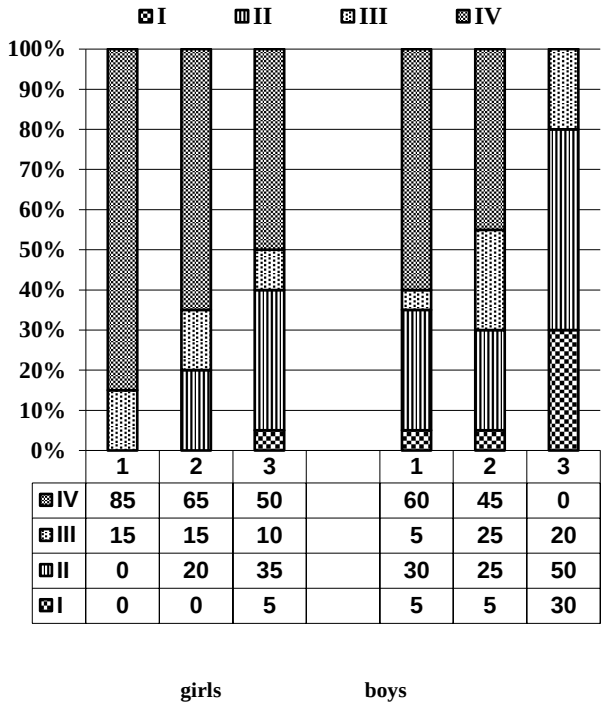


Figure 2. The distribution of schoolchildren of three age groups by individual indicators of performance of Stange test: I – high, II – above average, III – average, IV – below average level of physical development and somatic health.

The results of the Genchi test performed by schoolchildren, breath retention on exhalation are clearly shown in Figure 3. According to it, the reserve capabilities of the respiratory system in most 11-13-year-old girls and boys are reduced and this is associated with a decrease in energy resources and falling of the functional capabilities of the body. A high percentage of schoolchildren with good and excellent respiratory reserve capabilities were found among boys in each age group, especially in 14-15-year-olds.

The average values of MOC and work capacity during the performance of the step test by schoolchildren are shown in Table 3.



	1	2	3		1	2	3
IV	85	65	50		60	45	0
III	15	15	10		5	25	20
II	0	20	35		30	25	50
I	0	0	5		5	5	30

Figure 3. Indicators of the duration of breath retention in Genchi test: I – excellent, II – good, III – average, IV – poor state of the respiratory system.

Table 3. Absolute and relative indicators of dynamometry in schoolchildren

Indicators, un.	Boys	Girls
	M±m, min- max	M±m, min-max
11 years old	n =20	n = 20
MOC, ml/min/kg	51.0±3.35*	39.2±2.62
12-13 years old	n = 20	n = 20
MOC, ml/min/kg	48.1±2.10*	38.2±4.40
14-15 years old	n = 20	n =20
MOC, ml/min/kg	51.2±4.05	40.8±3.11

Note: * p≤0.05 in comparison between the boys and girls of the same age.

According to these parameters, it was established that in boys of all age groups, the relative value of MOC corresponded to a high level of physical performance. Since it was exceeded the upper limit of the age norm by 8.5% in 11-year-olds, by 6.9% in 12-13-year-olds, and by 7.8% in 14-15-year-olds. Boys aged 11-13 had higher MOC values (p≤0.05) compared to girls of the same age. In girls aged 11 and 12-13, the average relative values of MOC were reduced against the norm, which indicates they have a low level of energy capabilities and physical performance. In 14-15-year-old girls, this indicator is marked within the lower limit of the norm.

4. Discussion

Muscle fatigue and increased muscle performance are called post-activation potentiation [56]. The post-activation potential is defined as an increase in force generation following maximal or near-maximal muscle action and may be due to myosin light chain phosphorylation [57, 58]. The next potential mechanism of potentiation after activation could be an increase in calcium concentration at the bridge bridges and an increase in the excitability of alpha motor neurons [59]. Post-activation potentiation appears to be achieved when stimulation of the central nervous system causes an increase in contractile function due to stimulation of intense readiness [60]. Post-activation potentiation strategies generally involve performing dynamic or sub-maximum or sub-maximum power movements [61].

We believe that the low level of physical development, weak development of the muscular apparatus and physique in most adolescents is associated with a lack of motor activity, low levels of physical activity [62]. Low HSI values in adolescents are due to excess body weight [63]. A high level of physical development and health was revealed in a smaller part of schoolchildren.

A wide range of individual data points to the not simultaneous entry of students of the same age into the period of puberty. This pattern of physical development is genetically determined and related to the heterochronous processes [64]. First, there is an intensive growth of the body in length, and then a period of getting weight [65]. Another significant factor is the lack of proper level of motor activity of schoolchildren during the day.

Motor activity is a biological need and is caused by social factors. The body itself regulates the daily value of a motor activity, providing a constant amount of daily energy expenditure. This process is necessary for the normal growth and development of the body [66, 67, 68]. Lack of motor activity during the day leads to hypokinesia, and its excess leads to hyperkinesia, which is estimated as an excessive stimulus that is associated with excessive energy consumption [47].

The values of the average values of LI in all groups of schoolchildren were found in the range below the average value (Table 2), which was due to excess body weight in adolescents. These results indicated that under normal physiological conditions, adolescents experience a hypoxic effect due to insufficient levels of oxygen saturation in the body.

According to the results of the Stange test a high percentage of boys with a low level of the functional state of the respiratory system, mainly among 14-15-year-olds was revealed. This result is due to the fact that boys at this age stage have the most intensive and heterochronous growth processes of various organs and systems of the body, which require high energy consumption and consequently reduce the adaptive capabilities of the body.

5. Conclusion

Thus, the results of studying the functions of the external respiratory system showed:

1. Weak body type and weak muscle development in 70% of girls aged 11 and 14-15 years old, 50% of boys aged 11-15 years old; good body type – in 30% of boys aged 11-13 years old, strong-in 20% of boys aged 14-15 years old;

2. The strength of the muscles of both hands was reduced in 11-year-old boys against age norms by 20%; on average, by 25% in girls of all groups. According to individual HIS values, a low level of physical development and somatic health was detected in 80% of 11-15-year-old girls, 80% of 11-year – olds and 40% of 13-15-year-old boys; average-in 25% of 13-15-year-olds, above average and high in 15% of boys;

3. The values of VLC in all age groups of boys and girls were reduced against the norm by 10-15%, the values of average values of LI corresponded to below the average level of physical development in all groups of schoolchildren.

4. Low aerobic potential according to the results of Stange test was established in 14-15-year-old girls. The percentage of girls with average and higher aerobic respiratory capabilities prevailed among 11-13-year-olds. The results of Stange test showed a high percentage of boys with a low level of functional state of the respiratory system, especially among 14-15-year-olds.

5. The results of Genchi test revealed a decrease in the aerobic capacity of the respiratory system in the majority of girls and boys aged 11-13 years old. The high percentage of people with good and excellent aerobic capabilities of the respiratory system was identified among the boys of all age groups, especially in 14-15-year-olds.

6. The relative value of MOC corresponded to a high level of aerobic potential and physical performance in all age groups of boys. In 14-15-year-old girls, the average relative values of MOC corresponded to the norm, while in 11-13-year-old girls they were reduced and corresponded to a low level of aerobic potential and physical performance.

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