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The role of somatotype and body mass composition in the cardiovascular system adaptation during physical exercise in females from the lowland regions of Zakarpattia

Introduction. Adaptation to the performance of physical work is characterized by the ability of the cardiovascular system to recover to its original level after cessation of exercise. In recent years, research into the constitutional features and adaptive capabilities of healthy children and those with acquired or congenital pathology has intensified due to the fact that the constitution is determined not only by the degree of human adaptation to a wide variety of external environmental influences, but also by susceptibility to diseases and the nature of their course. Somatometry is widely used to renovate standards and indicators for assessment of the health of the younger generation. The anthropometric approach with the determination of the parameters of physical development and the body mass composition is ideal for monitoring health and physical status.

The purpose of the study is to determine the peculiarities of the recovery of the cardiovascular function according to the indicators of the recovery of the heart rate and blood pressure after dosed physical exercise in females of the lowland districts of Zakarpattia, depending on the somatotype and the component composition of body mass.

Materials and methods. 118 females aged 16-20, residents of the lowland regions of Transcarpathia, participated in the study. The assessment of the dynamics of cardiovascular system indicators depending on the constitutional characteristics of body composition was carried out by methods of heart rate monitoring, sphygmomanometry, bicycle ergometry, determination of somatotype using caliper and bioimpedancemetry, as well as statistical processing of research materials using Microsoft Excel 2010 spreadsheets.

Results and discussions. In the course of the research, we were able to establish that in some representatives of lowland areas dosed exercise on a bicycle ergometer caused a negative reaction of blood vessels. The number of females with increased diastolic pressure after performing work with a power of 1 W per 1 kg of body weight was 6.78%, and after performing work with a power of 2 W per 1 kg of body weight, the number of such persons was 5.1%. The phenomenon of “infinite tone”, which disappeared within 1 minute after cessation of exercise, gives reason to evaluate it as a physiological reaction of arterial vessels to the load, was observed in 7.63% of females only after performing work with a power of 2 W per 1 kg of body weight. When analyzing the dynamics of changes in diastolic pressure during dosed exercise in girls from the lowland regions of Zakarpattia, depending on the somatotype, we found that the highest percentage of persons with increased diastolic pressure after performing work with a power of 1 W per 1 kg of body weight was observed in ectomorphs and mesoectomorphs, which was 16.7% and 18.2% of the total number of examined. Functional capabilities of the cardiovascular system according to the indicator of changes in diastolic pressure depended on the content of the muscle and fat component of body mass, namely: the largest number of such persons, 11.9%, was registered among females with a relatively high content of muscle component (30.4 – 35.3%); in 7.14% of persons with a high relative content of the muscle component, dosed work on a cycle ergometer with a power of 2 w per 1 kg of body weight caused an increase in diastolic pressure; the largest percentage of persons, namely 25.0%, who had diastolic pressure above the initial level during dosed work on a cycle ergometer with a power of 1 W per 1 kg of body weight, was found in females with a low relative fat content (33.0 – 38.9%).

Conclusions. Our research are characterized by the fact that during exercise with an intensity of 1 W per 1 kg of body weight, the highest percentage of those in whom diastolic pressure increases is observed in lowland females of ectomorphic and mesoectomorphic somatotypes. That is, the insufficiency of the fat component of the body mass of females from lowland areas is manifested by a negative reaction of blood vessels, namely an increase in diastolic pressure above the initial level.

Key words: cardiovascular reaction, biological anthropology, post-workout recovery.

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Роль соматотипу та компонентного складу маси тіла в адаптації серцево-судинної системи у дівчат низинних районів Закарпаття під час фізичного навантаження

Вступ. Адаптація до виконання фізичної роботи характеризується здатністю серцево-судинної системи відновлюватися до вихідного рівня по її припиненню. За останні роки намітилася тенденція до збільшення досліджень конституційних особливостей та адаптаційних можливостей здорових і хворих дітей (з набутою або вродженою патологією), через те, що конституція зумовлена не лише ступенем адаптації людини до найрізноманітніших зовнішньосередовищних впливів, а також схильністю до виникнення хвороб і характером їх перебігу. Соматометрію широко використовують з метою відновлення стандартів та індексів для оцінки стану здоров'я підростаючого покоління. Саме антропометричний підхід з визначенням параметрів фізичного розвитку та компонентного складу тіла є ідеальним для здійснення моніторингу здоров'я та фізичного статусу.

Мета. Встановити особливості відновлення функції серцево-судинної системи за показниками відновлення частоти серцевих скорочень і артеріального тиску після дозованої фізичної роботи у дівчат низинних районів Закарпаття залежно від соматотипу та компонентного складу маси тіла.

Матеріали та методи. В дослідженні брали участь 118 дівчат від 16-20 років, мешканки низинних районів Закарпаття. Оцінку динаміки показників серцево-судинної системи залежно від конституційних характеристик складу тіла здійснювали методами

моніторингу серцевого ритму, сфігмоманометрії, велоергометрії, визначення соматотипу із застосуванням каліперометрії та біоімпедансометрії, а також статистичної обробки матеріалів дослідження із застосуванням електронних таблиць Microsoft Excel 2010.

Результати та обговорення. У ході дослідження нам вдалося встановити, що серед представниць низинних районів були особи, у яких дозована робота на велоергометрі викликала негативну реакцію судин. Кількість дівчат із підвищеним діастолічним тиском після виконання роботи потужністю 1 Вт на 1 кг маси тіла становила 6,78%, а після виконання роботи потужністю 2 Вт на 1 кг маси тіла кількість таких осіб становила 5,1%. «Феномен нескінченного тону», який зникав протягом 1-ої хв по припиненню роботи, дає підставу оцінювати його як фізіологічну реакцію артеріальних судин на навантаження, спостерігався у 7,63% дівчат лише після виконання роботи потужністю 2 Вт на 1 кг маси тіла. При аналізі динаміки змін діастолічного тиску при дозованих фізичних навантаженнях у дівчат низинних районів Закарпаття, залежно від соматотипу ми встановили, що найбільший відсоток осіб із підвищеним діастолічним тиском після виконання роботи потужністю 1 Вт на 1 кг маси тіла спостерігався у ектоморфів та мезоектоморфів, що становило 16,7% та 18,2% від усієї кількості обстежених. Можливості серцево-судинної системи за показником змін діастолічного тиску залежали від вмісту м'язового та жирового компоненту маси тіла, а саме: найбільше таких осіб 11,9% зареєстровано було серед дівчат з відносним високим вмістом м'язового компоненту (30,4 – 35,3 %); у 7,14% осіб з високим відносним вмістом м'язового компоненту дозована робота на велоергометрі потужністю 2 Вт на 1 кг маси тіла викликала підвищення діастолічного тиску; найбільший відсоток осіб, а саме 25,0%, які мали діастолічний тиск вище вихідного рівня, при дозованій роботі на велоергометрі потужністю 1 Вт на 1 кг маси тіла, виявлено у дівчат з низьким відносним вмістом жиру (33,0 – 38,9 %).

Висновки. Наші дослідження характеризуються тим, що при виконанні роботи інтенсивністю 1 Вт на 1 кг маси тіла у дівчат низинних районів ектоморфного та мезоектоморфного соматотипів спостерігається найбільший відсоток тих, у кого підвищується діастолічний тиск. Тобто, недостатність жирового компоненту маси тіла дівчат низинних районів проявляється негативною реакцією судин, а саме підвищенням діастолічного тиску вище вихідного рівня.

Ключові слова: серцево-судинна реакція, біологічна антропология, посттренувальне відновлення.

Introduction. Adaptation to the performance of physical work is characterized by the ability of the cardiovascular system to recover to its original level after cessation of exercise. The impact of stressors on the human body, including meteorological and geographical factors (altitude above sea level, temperature, and pollution), requires the study and improvement of the adaptive mechanisms of the functioning of individual organs and systems [1, 2, 3, 10]. The body mass composition, in particular the ratio of muscle and fat tissue, determines the effectiveness of cardiovascular system adaptation during physical exertion. The works of scientists [2, 5, 7, 8, 9, 14] convincingly prove that modeling the training of athletes based on somatological characteristics allows to increase effectiveness. In recent years, research into the constitutional features and adaptive capabilities of healthy children and those with acquired or congenital pathology has intensified due to the fact that the constitution is determined not only by the degree of human adaptation to a wide variety of external environmental influences, but also by susceptibility to diseases and the nature of their course. Anthropometric and somatological studies allow to link the structural features of the human body with the features of the metabolism and functions of the body in normal conditions and in the presence of a pathological process. Somatometry is widely used to renovate standards and indicators for assessment of the health of the younger generation [4, 12, 13, 20]. Since anthropology has reoriented from purely determining the body forms and proportions to their influence on the body's functions, the study of hereditary and environmental variability at various stages of the organization and functioning of the human body is relevant [10, 17]. It is also important to study somatological and functional body features of persons who live on certain territories. Thus, scientists conducted a comparative characterization of the level of physical development of post-puberty individuals in the Podilsk region, the Carpathian region, the Zakarpattia region, as well as children and adolescents in Bulgaria (Smolyan province and the city of Plovdiv). In this study, they described height, limb length, the relative content of the muscle and fat components, somatotype, as well as

adaptive capabilities of the organism in aerobic and anaerobic modes of energy supply depending on the constitutional features of the body structure [7, 15, 16, 18]. The anthropometric approach with the determination of the parameters of physical development and the body mass composition is ideal for monitoring health and physical status [18, 19].

The purpose of the study is to determine the peculiarities of the recovery of the cardiovascular function according to the indicators of the recovery of the heart rate and blood pressure after dosed physical exercise in females of the lowland districts of Zakarpattia, depending on the somatotype and the component composition of body mass.

Methodology and methods of research. 118 healthy females aged 16-20 years living in the lowland areas of Zakarpattia, located at an altitude below 400 meters above sea level, took part in the study. The number of individuals was 53.6% of the total number of examined females. The study was carried out on the basis of the Department of Surgical Dentistry and Clinical Disciplines Uzhhorod National University. In the process of the ascertaining experiment, heart rate monitoring using a TOPCOM HB 8M00 chest pulse sensor and sphygmomanometry was used. Observation, registration and analysis of adaptive changes in the functional indicators of the cardiovascular system were carried out during cycle ergometry after two loads with a power of 1 W/kg and 2 W/kg with an interval of 5 minutes immediately after workout and three times after its completion (after 1, 2 and 3 minutes) [2, 9, 11]. When conducting tests to assess physical performance, we took into account the physiological features of the female body. However, such tests were not conducted during the ovulation (13-14th day), premenstrual (26-28th day) and menstrual phase of the ovarian cycle [14]. According to the Heath-Carter method, somatotype was determined using a Digital Body Fat Caliper, a centimeter tape and an electronic metal Digital Caliper 150 mm [6]. The component composition of body mass was determined by the method of bioelectrical impedance, assessing the total content of the fat component according to the criteria of H.D. McCarthy and D. Gallagher, muscle component by Omron Healthcare, using the Body Composition Monitor device OMRON BF511 [8]. Statistical pro-

cessing of the research results was carried out using Microsoft Excel 2010 spreadsheets, which allowed to analyze the measurements and calculations of the obtained values.

Results and discussion. We studied the dynamics of heart rate recovery after performing physical exercise mainly in aerobic (with stimulation of aerobic) and anaerobic (with stimulation of anaerobic lactic) metabolism in females from the lowland areas of Zakarpattia region without taking into account the somatotype and component composition of body mass (Table 1.).

In the first minute of the recovery period, the amount of heart rate reduction after performing work in the aerobic mode of energy supply almost does not depend on the intensity of the load, however, the tendency to increase the difference in the recovery speed appeared later. Thus, when the heart rate increased to 130-140 bpm⁻¹, it decreased on average by 34.3±1.08 bpm⁻¹ 120 s after cessation of exercise, and at a rate of 180-190 bpm⁻¹ it decreased by 48.6±0.98 bpm⁻¹. After 180 s of the recovery period, at a heart rate of 130-140 bpm⁻¹, its decrease was on average 36.7±1.43 bpm⁻¹, and at a frequency of 180-190 bpm⁻¹ it was 53.7±1,38 bpm⁻¹. Moreover, the decrease in heart rate slows down significantly from 120 s to 180 s of the recovery period.

The analysis of the reaction of arterial vessels to dosed physical work turned out to be an important aspect of our research. It is known that loads of a cyclic nature cause a characteristic reaction of arterial vessels, which is normally manifested by an increase in systolic and unchanged or a decrease in diastolic pressure. An increase in systolic pressure is mainly associated with an increase in the force of heart contractions and an increase in vascular tone, and a decrease in diastolic pressure is associated with the expansion of arterioles in working muscles. An increase in diastolic pressure is regarded as a negative reaction of blood vessels to physical exertion and indicates labile hypertension or hypertensive disease. Given the peculiarities of blood pressure determination using the Riva-Rocci method, some people experience the so-called phenomenon of "infinite tone", which is manifested by audible Korotkoff

tones when the manometer needle drops to the zero mark.

It is known that lowering DBP to zero level is not compatible with life. In cases of registration of the phenomenon of "infinite tone", the DBP corresponds to a value of about 50 mmHg. Therefore, the numerical value of the DBP of persons in whom the phenomenon of "infinite tone" was observed was not subject to registration. The results of such a study without taking into account the somatotype and the component composition of the body mass of the examined females are shown in table 2.

In the course of the research, we were able to establish that in some representatives of lowland areas dosed exercise on a bicycle ergometer caused a negative reaction of blood vessels. The number of females with increased diastolic pressure after performing work with a power of 1 W per 1 kg of body weight was 6.78%, and after performing work with a power of 2 W per 1 kg of body weight, the number of such persons was 5.1%. The phenomenon of "infinite tone", which disappeared within 1 minute after cessation of exercise, gives reason to evaluate it as a physiological reaction of arterial vessels to the load, was observed in 7.63% of females only after performing work with a power of 2 W per 1 kg of body weight.

When analyzing the dynamics of changes in diastolic pressure during dosed exercise in girls from the lowland regions of Zakarpattia, depending on the somatotype, we found that the highest percentage of persons with increased diastolic pressure after performing work with a power of 1 W per 1 kg of body weight was observed in ectomorphs and mesoectomorphs, which was 16.7% and 18.2% of the total number of examined (Table 3). During a cycle ergometric load with an intensity of 1 W per 1 kg of body weight in females, the number of people with diastolic pressure equal to the initial level and lower than the initial level increases due to a decrease in the number of those with the phenomenon of "infinite tone". Among females of all somatotype groups, a decrease in the number of individuals with increased diastolic pressure is observed after performing work with a power of 2 W per 1 kg of body mass.

Table 1

Dynamics of heart rate recovery after exercise in females from lowland districts, n=118

Increase in HR during exercise, bpm ⁻¹	Decrease in HR (bpm ⁻¹) after the completion of exercise, M±m					
	after 10 s	after 20 s	after 30 s	after 60 s	after 120 s	after 180 s
130 – 140	7,1±0,48	15,4±0,58	19,7±1,00	32,2±1,04	34,3±1,08	36,7±1,43
180 – 190	8,6±0,51	18,3±1,03	23,9±0,92	37,4±1,34	48,6±0,98	53,7±1,38

Table 2

The types of changes in diastolic pressure during dosed physical exercise in females from lowland districts, n=118

Load capacity	Type of diastolic pressure changes, mm.Hg, M±m							
	Below the initial level		Equal to the initial level		Phenomenon of "infinite tone"		Above the initial level	
	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m
1 W·kg ⁻¹	65,25	63,9±0,83	27,97	75,2±1,27	-	-	6,78	77,5±2,65
2 W·kg ⁻¹	64,41	58,2±0,84	22,88	75,6±1,47	7,63	*	5,08	82,5±2,65

Note: * – the data were not presented numerically.

At the same time, the largest number of individuals whose diastolic pressure level exceeded the baseline was observed among ectomorphs and mesoectomorphs, which amounted to 8.3% and 9.1%, respectively.

As the data in the table 4 show, functional capabilities of the cardiovascular system according to the indicator of changes in diastolic pressure depended on the content of the muscle component of body mass, namely: among females of all somatotype groups there were individuals whose diastolic pressure exceeded the initial level.

The largest number of such persons, 11.9%, was registered among females with a relatively high content of this component (30.4 – 35.3%). In 7.14% of persons with a high relative content of the muscle component, dosed work on a cycle ergometer with a power of 2 W

per 1 kg of body weight caused an increase in diastolic pressure.

The phenomenon of “infinite tone” was observed in females who performed work on a bicycle ergometer with an intensity of 2 W per 1 kg of body weight, regardless of the content of the muscle component.

As shown by the data in Table 5, the state of the cardiovascular system in terms of changes in diastolic pressure depended on the content of the fat component in the examined subjects: the largest percentage of persons, namely 25.0%, who had diastolic pressure above the initial level during dosed work on a cycle ergometer with a power of 1 W per 1 kg of body weight, was found in females with a low relative fat content (33.0 – 38.9%). The phenomenon of “infinite tone” was observed in

Table 3

The types of changes in diastolic pressure during dosed physical exercise in females from lowland districts depending on somatotype, n=118

Load capacity	Type of diastolic pressure changes, mm. Hg., M±m							
	Below the initial level		Equal to the initial level		Phenomenon of “infinite tone”		Above the initial level	
	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m
Endomesomorphs (n=38)								
1 W·kg ⁻¹	68,5	64,2±1,77	28,9	75,5±2,99	-	-	2,6	85,0
2 W·kg ⁻¹	65,8	59,6±1,30	26,3	74,0±3,25	5,3	*	2,6	90,0
Endomorphs (n=16)								
1 W·kg ⁻¹	75,0	61,7±2,31	18,7	70,3±2,09	-	-	6,3	75,0
2 W·kg ⁻¹	62,5	56,0±1,62	18,7	70,7±1,26	12,5	*	6,3	78,0
Mesoectomorphs (n=11)								
1 W·kg ⁻¹	45,5	66,0±4,29	36,3	75,0±2,80	-	-	18,2	72,5±13,27
2 W·kg ⁻¹	54,5	63,3±3,54	27,3	76,7±4,18	9,1	*	9,1	85,0
Ectomorphs (n=12)								
1 W·kg ⁻¹	50,0	63,3±1,77	33,3	65,0±2,80	-	-	16,7	80,0±8,85
2 W·kg ⁻¹	58,4	55,8±3,02	25,0	63,3±4,18	8,3	*	8,3	90,0
Balanced somatotype (n=41)								
1 W·kg ⁻¹	68,3	64,3±1,19	26,8	80,0±1,99	-	-	4,9	77,5±4,42
2 W·kg ⁻¹	68,3	57,0±0,96	19,5	77,5±4,42	7,3	*	4,9	83,8±1,32

Note: * – the data were not presented numerically;

Table 4

The types of changes in diastolic pressure during dosed physical exercise in females from lowland districts depending on the muscle content of the body composition, n=118

Load capacity	Type of diastolic pressure changes, mm. Hg., M±m							
	Below the initial level		Equal to the initial level		Phenomenon of “infinite tone”		Above the initial level	
	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m
Normal skeletal muscle content (24,3 – 30,3 %), n=76								
1 W·kg ⁻¹	71,05	63,4±1,05	25,00	76,3±1,92	-	-	3,95	78,3±4,18
2 W·kg ⁻¹	68,42	57,5±0,77	21,05	76,3±2,19	6,58	*	3,95	80,0±6,28
High skeletal muscle content (30,4 – 35,3 %), n=42								
1 W·kg ⁻¹	54,76	65,0±1,38	33,33	73,6±1,63	-	-	11,90	77,0±4,29
2 W·kg ⁻¹	52,38	58,6±1,14	30,95	73,9±1,73	9,52	*	7,14	85,0±4,18

Note: * – the data were not presented numerically;

The types of changes in diastolic pressure during dosed physical exercise in females from lowland districts depending on the fat content of the body composition, n=118

Load capacity	Type of diastolic pressure changes, mm. Hg., M±m							
	Below the initial level		Equal to the initial level		Phenomenon of "infinite tone"		Above the initial level	
	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m	Number of persons, %	DBP, mm.Hg, M±m
Low fat content (< 21,0 %), n=8								
1 W·kg ⁻¹	50,0	62,5±2,80	25,0	70,0±17,69	-	-	25,0	70,0±8,85
2 W·kg ⁻¹	62,5	62,0±6,44	25,0	70,0±17,69	12,5	*	-	-
Normal fat content (21,0 – 32,9 %), n=65								
1 W·kg ⁻¹	64,62	64,4±0,90	27,7	76,1±2,0	-	-	7,69	79,0±2,15
2 W·kg ⁻¹	64,62	57,4±0,72	20,0	78,5±2,59	7,69	*	7,69	81,0±3,22
High fat content (33,0 – 38,9 %), n=45								
1 W·kg ⁻¹	68,89	63,4±1,56	28,89	74,6±2,59	-	-	2,22	85,0
2 W·kg ⁻¹	64,44	58,6±1,16	26,67	68,3±8,32	6,67	*	2,22	90,0

Note: * – the data were not presented numerically;

females from lowland areas only during cycle ergometric exercise with an intensity of 2 W per 1 kg of body weight.

Conclusions. The conducted studies proved that in the examined lowland females the dynamics of heart rate recovery after work on a bicycle ergometer, which increased the heart rate to 130-140 bpm⁻¹ (in the aerobic mode of energy supply), is significantly slower than after work that caused an increase in heart rate to 180-190 bpm⁻¹ (with stimulation of anaerobic lactic processes of energy supply), and the beginning of a significant decrease is noted after 120 s.

Differences in the reaction of arterial vessels to dosed physical exertion were revealed depending on the somatotype and the component composition of the body. They are characterized by the fact that during exercise with an intensity of 1 W per 1 kg of body weight, the highest percentage of those in whom diastolic pressure increases is observed in lowland females of ectomorphic and mesoectomorphic somatotypes. That is, the insufficiency of the fat component of the body mass of females from lowland areas is manifested by a negative reaction of blood vessels, namely an increase in diastolic pressure above the initial level.

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