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FUNCTIONAL CAPABILITIES OF CARDIOVASCULAR SYSTEM OF ADOLESCENTS

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Abstract
We have studied functional capabilities of cardiovascular system in young men of service age in terms of indicators of cardiointervalography. It was stated that people who are 18-21 years old demonstrate increase of values of systolic, diastolic pressure and heart rate after physical activity in comparison with the values obtained in the rest state, while range values of P, Q, R, S and T deflections, interval sizes of P-Q, QRS and Q-T, reference and actual reference systole and systolic indicator decrease. Vagosympathetic index of the test persons after the functional test increased as compared with the rest state, which provides evidence of increase in tonus of sympathetic nervous system after physical activity.
Key words: young men who are subject to conscription / conscripts, cardiovascular system, cardiointervalography, functional test.

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ФУНКЦИОНАЛЬНЫЕ ВОЗМОЖНОСТИ СЕРДЕЧНО-СОСУДИСТОЙ СИСТЕМЫ У ЛИЦ ЮНОШЕСКОГО ВОЗРАСТА

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Аннотация
Изучены функциональные возможности сердечно-сосудистой системы юношей призывного возраста по показателям кардиоинтервалографии. Установлено, что у 18-21-летних испытуемых после физической нагрузки в сравнении с состоянием покоя показатели систолического, диастолического давления и ЧСС увеличиваются, значения амплитуды зубцов P, Q, R, S и T, длительности интервалов P-Q, QRS и Q-T, должной и фактической электрической систолы и систолического показателя снижаются. Вагосимпатический индекс у испытуемых после функциональной пробы повышается в

сравнении с покоем, что свидетельствует о повышении тонуса симпатической нервной системы после физической нагрузки.
Ключевые слова: юноши-призывники, сердечно-сосудистая система, кардиоинтервалография, функциональная проба.

Health protection of young men of service age is an essential problem, since during this period of ontogenesis various morphological and functional changes of organs and systems of human body happen, which condition certain vulnerability of the organism to development of a range of diseases [15].

Youthful age is characterized by the most significant susceptibility to harmful influences of environmental factors. In conditions of political, social and economic changes in the country that have recently conditioned deterioration of quality of life, decline in living standards of people and social tension, young men become one of the vulnerable social groups. Analysis of their health state over time shows that with aging we may observe more young men with abnormalities of physical development. We worry much about state of health of young men of service age and increase of the number of young men who are subject to conscription, but who are unserviceable due to medical reasons [2].

Leading criteria of health condition of young men of service age is physical development, the level of which is closely connected with social, economic and hygienic living conditions [14]. Normal physical, nervous and mental development and functioning of all organs and systems of conscripts' bodies condition capabilities of their organisms to keep resistance to exogenic factors, to adapt to changing conditions of outer environment. Young men who have deviations in state of health, also usually have adaptive capabilities that are lower than the one ones of their apparently healthy peers [2]. An essential element of monitoring of health state is observation over the growth and development of young men who are standing at the cusp of adult life with its social requirements, increases physical and mental pressure in conditions of military service. Success of their adaptation may play an important role in future reproductive and labor potential of the country, its development and level of national security [15].

Organisms of adolescents demonstrate significant alterations in correlation of heart and vessels' growth, which lead to peculiar conditions of blood circulation. That is why military age requires attentive and differentiated approach in terms of dosage of physical load, so that there would be no overload, at the same time, physical activities should provide necessary training of cardiovascular system.

Basing on the abovementioned, study of functional state of conscripts' cardiovascular system at rest and after physical load is considered to be topical.

The subject of the work: to study functional capabilities of cardiovascular system of adolescents.

Materials and methods of the research

The studies have been performed on the base of Functional Diagnostics Department of municipal health care institution of city hospital No. 2 of Belgorod. Four groups of conscripts at the age of 18-21 were examined. In each group, there were 25 test persons of youthful age.

Physical development of conscripts was defined with the help of anthropometry method. From the multitude of anthropometric attributes, we selected the following ones: somatometric ones (we measured height and body mass, chest circumference), physiometric ones (we measured arterial pressure (AP) according to Korotkov's technique in the left brachial artery and heart rate (HR)). All anthropometric examinations were performed according to generally accepted methods [4].

Registration of ECG data was performed in relative rest condition – while the patient was lying on one's back after preliminary rest during 5 minutes, as well as on the 3^{rd} and 6^{th} minutes after the load with 150 W at cardiac stress test apparatus (orthostatic test with load) [6]. ECG recording was performed with the help of electrocardiograph "Aksion" at standard amplification of 1 mV=10 mm, with the speed of tape transport mechanism that equaled 50 mm/s, in 12 common leads: in three standard ones (I, II, III) single-pole ones, amplified from the limbs (aVR, aVL, aVF) and six single-pole amplified chest ones (V_1–V_6). While using deflection nomenclature of PQRST complex, ECG indicators of the II lead were assessed: basic cycle length, heart rate, amplitude of deflections P, Q, R, S and T, length of P-Q, QRS, S-T and Q-T intervals [12]; also, we calculated indicators – interactive one (II) as a relation of amplitude of deflections P and T [12], systolic showing (SI) according to Fogelson-Chernogorov's formula: (Q-T/R-R) 100%. Proper electric systole was defined according to Bazett's formula: $Q\text{-}T_{false} = K\sqrt{R\text{-}R}$, where K is a constant that equals 0.37 for men and 0.39 for women.

Obtained digital material was statistically processed with the help of personal computer [5]. At definition of statistically significant difference between the groups, we used Student's criteria and tables of Fisher and Snedecor for calculation of significance criteria. Results were considered as valid ones, starting from the value $p<0.05$.

Results of the research and their discussion

Obtained values of physical development indices of conscripts are presented in Table 1.

As it can be seen from the data presented in the Table 1, all anthropometric indices of the tested persons were within the limits of physiological norms [10].

Table 1

Indices of physical development of conscripts

Parameters, Units of measurement	Age, years			
	18	19	20	21
Height, cm	164.5±3.9	172.40±2.83	174.00±4.28	176.00±4.21
Body mass, kg	63.5±4.5	76.20±3.20#	72.00±4.32	73.50±3.25
Chest circumference, cm				
Inhale	90.21±1.50	95.45±1.41#	97.25±1.93	98.30±1.75
Exhale	81.42±1.83	86.34±1.24#	86.50±1.50	90.50±1.62
Pause	84.80±1.94	83.71±1.50	89.25±1.65&	87.60±1.72

Note: statistical significance: # - in comparison with the 18-year old, & -- in comparison with the 19-year old according to Student's t-criterion ($p<0.05$).

Body mass of the tested persons aged 19 as compared with the 18-year old ones was larger by 20%, which indicated at intensive building up of muscle mass in 19-year old conscripts. Chest circumference of young men increases with age at almost all functional conditions. At the same time, statistically significant increase of this indicator is registered at the age of 19 at inhale and exhale by 5.81% и 6.04%, respectively in comparison with the 18-year old adolescents, while at the age of 20 this parameter demonstrates increase at pause by 6.62% in comparison with the 19-year old adolescents.

Arterial blood pressure rate that characterizes function of cardiovascular system, also corresponded to age norm [8] (Table 2).

Table 2

Functional state of conscripts

Parameters, Units of measurement	Age, years			
	18	19	20	21
Systolic blood pressure, mm Hg. - before the activity -after the activity	118.0±3.88 149.0±4.33*	110.0±4.14 149.0±2.76*	124.0±2.49 166.5±2.11*	124.5±2.83 173.5±1.97*
Diastolic blood pressure, mm Hg. - before the activity -after the activity	77.0±2.13 86.0±2.21*	76.5±1.83 85.0±1.66*	80.0±1.22 87.0±1.53*	81.0±1.80 88.5±1.83*
Pulse pressure, mm Hg - before the activity -after the activity	41.0±2.33 63.0±4.72*	33.5±3.45 64.0±2.66*	45.0±1.67 78.5±2.36*	43.5±1.50 85.0±2.35*
Mean dynamic pressure, mm Hg. - before the activity -after the activity	90.6±2.62 106.96±2.14*	88.8±2.19 106.33±1.68*	97.6±1.93 118.49±2.35*	95.46±2.07 117.49±1.32*
Heart rate, bpm. - before the activity -after the activity	82.7±1.48 154±3.11*	81.8±0.89 162±2.56*	82.3±0.79 161.2±3.05*	79.0±2.73 163.6±3.57*

Note: from now on: * means statistically significant differences in comparison with showings, obtained before the activity according to Student's t-criteria ($p<0.05$).

After physical activity conscripts who were 18, 19 and 20 years old and tested persons of 21-year-old systolic pressure was higher by 26%, 35%, 34% and 39%, diastolic pressure was higher by 12%, 11%, 9% and 9%, respectively, in comparison with rest state. This indicator was higher after functional probe was taken from tested persons who were 18, 19 and 20 years old and persons of 21-year-old by 54%, 91%, 74% and 95% in comparison with inactive state. Medium dynamic pressure that demonstrated energy of constant blood circulation, changed in the similar way.

Age-specific anatomical changes in cardiovascular system of adolescents are closely connected with changes in functional indices, one of which is a heart rate. This hemodynamic index is one of the most labile ones. It changes in the process of growth and depends on both environmental (environmental temperature, hungering) and internal (heart and endocrine diseases, anemia etc.) factors. It is generally known that with increase of motor performance, gain in weight of skeletal muscles, nervous regulation of heart rate is improved. At the same time, conscripts who are involved into sport activities, demonstrate bradycardic tendencies. This happens because intensive motional exercises cause physiologic hypertrophy of myocardium [3; 9]. In general, heart rate showings (in min) both at rest state and after physical activity were within the limits of physiological nor, at young men from all groups, while within the limits of normal values increase of

this index after physical load was observed. Thus, at the age of 18, 19, 20 and 21, this index after the load was higher in comparison with rest state, by 86%, 98%, 96% and 107%, respectively.

According to various authors, ECG showings (amplitude of deflections, length of intervals) vary greatly [6;7;12]. Basing on that, we compared background showings (at rest state) and showings, obtained after the physical activity.

Cardiac cycle length, which combines electrophysiological, biochemical and biophysical processes that occur in heart during one heart beat, was calculated according to R-R interval. During cardiac cycle five constant deflections were recorded (P, Q, R, S and T), showings of which are presented in Table 3.

As it can be seen from the Table 3, all indicators of deflections after physical load are reduced almost twice.

Deflection P, which characterizes conduction of excitement in atrium, after physical load in patients of 18, 19, 20 and 21 years old was lower by 48%, 37%, 50% and 50%, respectively as compared with rest state. At all groups, this deflection is a positive one, which characterizes sinus rhythm.

Deflection Q, which characterizes excitement of interventricular septum and cardiac apex, in examined conscripts who underwent physical load, reduced by 44%, 38%, 43% and 47%, respectively, at the ages of 18,19, 20 and 21.

Deflection R that characterizes excitement of the main mass of ventricles' musculature, except for the cardiac base and subepicardial layer, in examined conscripts who underwent physical load, reduced by 49%, 38%, 48% and 58%, respectively, after the physical load. At the same time, its values in both rest state and after physical activity was within limits of normal values.

Amplitude of S deflection, which reflects the state when all parts of ventricles are excited, except for their base, decreased by 50%, 38%, 54% and 53% after physical activity, performed by examined young men of 18, 19, 20 and 21 respectively, in comparison with the rest state.

Deflection T in patients who were 18,19, 20 and 21 years old also decreased by 46%, 43%, 54% and 57%, respectively, in comparison with rest state. It is known that physical activities that are accompanied with acceleration of heart beat, may give lead to myocardial hypoxia. The latter one is characterized with reduction and inversion of T deflections. More severe forms of myocardial hypoxia cause occurrence of giant positive deflections T. Occurrence of these changes are closely connected with peculiarities of spread of excitation from subendothelial to subepicardial layers of ventricle myocardium [12].

According to literature data [11; 13], flattening of T deflections may also correspond to metabolic changes in myocardium itself as a result of energy supply malfunction and misalignment of activity of central and autonomous structures of its regulation. In our test, amplitude of T deflection after physical activity in all experimental groups demonstrated a tendency to reduction, however, it was within the limits of physiological norm, which may be an evidence of the fact that with age adaptation to hypoxia improves, and regulatory function is stabilized.

Table 3

Indicators of amplitude of ECG deflections, mV

Parameters, units of measurement	Age, years			
	18	19	20	21
P - before the activity -after the activity	0.8±0.012 0.42±0.012*	0.7±0.009 0.44±0.016*	0.7±0.01 0.35±0.019*	0.9±0.007 0.45±0.013*
Q - before the activity -after the activity	0.8±0.008 0.45±0.012*	0.6±0.008 0.37±0.015*	0.7±0.009 0.40±0.010*	0.9±0.008 0.42±0.006*
R - before the activity -after the activity	0.8±0.008 0.41±0.009*	0.6±0.110 0.37±0.015*	0.8±0.008 0.38±0.007*	1.0±0.009 0.42±0.010*
S - before the activity -after the activity	0.8±0.011 0.40±0.006*	0.6±0.008 0.37±0.011*	0.7±0.009 0.32±0.010*	0.9±0.007 0.42±0.008*
T - before the activity -after the activity	0.8±0.012 0.43±0.02*	0.7±0.006 0.40±0.009*	0.8±0.01 0.37±0.010*	1.0±0.009 0.43±0.001*

Note: from now on: * means statistically significant differences in comparison with showings, obtained before the activity according to Student's t-criteria ($p<0.05$).

Apart from the amplitude of deflections, we studied intervals' length, results of which are presented in Table 4.

Table 4

Indicators of lengths of ECG intervals

Parameters, units of measurement	Functional state of conscripts			
	Age, years			
	18	19	20	21
PQ, s - before the activity -after the activity	0.08±0.002 0.07±0.002*	0.13±0.004 0.09±0.005*	0.11±0.003 0.09±0.004*	0.08±0.002 0.07±0.002*
QRS, s - before the activity -after the activity	0.06±0.002 0.05±0.001*	0.11±0.008 0.05±0.001*	0.05±0.006 0.05±0.003	0.07±0.004 0.07±0.002
QT, s - before the activity -after the activity	0.36±0.004 0.18±0.002*	0.28±0.005 0.15±0.006*	0.33±0.004 0.17±0.004*	0.31±0.006 0.18±0.003*

Note: from now on: * means statistically significant differences in comparison with showings, obtained before the activity according to Student's t-criteria ($p<0.05$).

As it can be seen from the table, after physical activity lengths P-Q intervals in conscripts who were 18, 19, 20 and 21 years old decreased by 13%, 31%, 18% and 13%, respectively, in comparison with the rest state. At the same time, this indicator in conscripts of 19 and 20 years was higher in comparison with 18- and 21-years old adolescents. It is known that correlation of the length of time intervals of cardiac cycles reflects association of vegetative mechanisms of regulation of heart's electrical activity [6]. Therefore, lowering of this indicator after physical activity in comparison with rest state in cardiac cycles' temporal structure of fraction of R-Q intervals may be considered as a result of dominating influence of sympathetic part of VNS in heart electric activity [7].

Length of QRS interval, which characterizes conduction of excitement through working myocardium of ventricles, after functional probe in examined persons of 18 and 19 years old reduced by 17% and 55%, respectively, in comparison with rest state. Tested persons who were 20 and 21 years old didn't demonstrate the change of this index.

Interval Q-T is one of the most important parameters for ECG assessment. Its prolongation is considered as a risk marker of dangerous ventricular arrhythmia; within the recent years, information about proarrhythmical character of shortening of Q-T occurred; also, criteria of "syndrome of short Q-T interval" are being defined. As it can be seen from Table 4, after physical activity conscripts aged 18, 19, 20 and 21 demonstrated Q-T intervals' length by 50%, 46%, 48% and 42%, respectively in comparison with the rest state. At the same time, all indices were within normal limits.

Length of Q-T interval from the beginning of Q peak till the end of T peak reflects the time, during which ventricles are in electrically active condition and are defined as electric systole. Length of electric systole changes depending on heart rate. Mathematic dependency between frequency of heart rate and length of Q-T interval. This is so-called reference electric systole. At normal heart condition, difference between actual and reference systole is not more than ±15%. Values of electric actual and reference systole that were obtained by us, meet these parameters, which speaks of normal distribution of cardiac impulses in examined groups of conscripts both in rest state and after functional test (Table 5).

Table 5

Indices of electric systole, systolic index and vagosympathetic index

Parameters, units of measurement	Functional state of conscripts			
	Age, years			
	18	19	20	21
Reference electric systole, s - before the activity - after the activity	0.33±0.002 0.25±0.002*	0.30±0.003 0.27±0.002*	0.38±0.003 0.24±0.003*	0.28±0.002 0.24±0.002*
Actual electric systole, s - before the activity - after the activity	0.36±0.004 0.18±0.002*	0.28±0.005 0.15±0.006*	0.33±0.004 0.17±0.004*	0.31±0.006 0.18±0.003*
Reference systolic index, % - before the activity - after the activity	0.44 0.57	0.55 0.48	0.66 0.57	0.65 0.56
Actual systolic index, % - before the activity - after the activity	0.53 0.41	0.5 0.26	0.78 0.40	0.72 0.42
Vagosympathetic index - before the activity - after the activity	100 110.25	85.71 102.5	100 94.59	100 104.65

Note: from now on: * means statistically significant differences in comparison with showings, obtained before the activity according to Student's t-criteria ($p<0.05$).

As it can be seen from the Table 5, after physical activity, reference electrical systole of conscripts aged 18, 19, 20 and 21 decreased by 24%, 10%, 37% and 14%, and actual electrical systole decreased by 50%, 46%, 48% and 42%, respectively, in comparison with the rest state.

Spread of excitation along cardiac muscle characterizes not only length of electric systole, but also so-called systolic index, which represents correlation of length of electric systole and duration of all cardiac cycle. In all experimental groups this index decreased after physical activity by 23%, 48%, 49% and 42% for persons who were 18, 19, 20 and 21 years old.

Vagosympathetic index characterizes correlation between amplitude of P deflection to T deflection. Increase of this index in conscripts aged 18, 19 and 21 after functional probe by 10%, 20% and 5%, correspondingly, in comparison with the rest state gives the evidence of increase in tonus of sympathetic nervous system after physical activity [12].

Conclusion

Anthropometric indices of the conscripts were within limits of physiological norm. Persons who were 18-21 years demonstrated increase of systolic pressure values after physical exercise in comparison with the rest state increased by 27-39%, and increase of diastolic pressure by 9-12%/ Their heart rate per minute increased by 86-107%. Against the background of the abovementioned indices after the activity, there have been observed decrease of amplitude of P, Q, R, S and T deflections in all experimental groups by 37-58%. Also, length of P-Q, QRS and Q-T intervals decreased by 13-55%, length of reference and actual electric systole decreased by 10-50%, and systolic index decreased by 23-49% as compared with the rest state. Vagosympathetic index of tested persons after functional probe increased by 5-20% in comparison with rest state, which indicates at tonus of sympathetic nervous system after physical activity.

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