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**INDO AMERICAN JOURNAL OF
PHARMACEUTICAL SCIENCES**<http://doi.org/10.5281/zenodo.910382>Available online at: <http://www.iajps.com>**Research Article****ADAPTIVE REACTIONS OF THE CARDIOVASCULAR
SYSTEM OF GIRLS OF DIFFERENT STAGES OF PUBERTY
ON PHYSICAL ACTIVITY DURING THE ACADEMIC YEAR****Alekei Anatolevich Zverev***, Alevtina Vasilevna Krulova, Tatiana Andreevna Anikina,
Marsel Muratchanovich Zaineev, Timur Lvovich ZefirovInstitute of Fundamental Medicine and Biology, Kazan Federal University, 18
Kremlyovskaya Street, Kazan, 420008, Russia.**Abstract:**

Controlled physical activity of moderate power working capacity (50% of PWC₁₇₀) causes a marked change in the cardiovascular system (stroke volume and minute blood volume, heart rate) in 11-16-year-old girls at different stages of puberty (stages 1-5). The reaction of urgent adaptation of girls' cardiovascular system to physical activity during the pubertal period depends on the level of their sexual maturity. The pronounced chronotropic effect of cardiovascular system is revealed in girls at the 1st and the 2nd stages of puberty in response to a functional test, during the academic year. The inotropic effect is more pronounced in girls at the 3rd -5th stages. There are moderate changes in the studied parameters in response to a functional test and their relatively rapid recovery to the background level in girls at the 1st and the 2nd stages of puberty. A long period of wave-like recovery of the studied parameters to the baseline level, with the appearance of "negative phase" of the heart rate recovery, was revealed in girls at the 3rd and the 4th stages of puberty, at the maximum reactions of stroke volume and minute blood volumes to physical activity. This is regarded as a sign of uneconomic response, unfavorable reaction of the cardiovascular system to the physical activity, the most pronounced at the end of the academic year. The reactions of urgent adaptation of the cardiovascular system to the controlled physical activity during the academic year are characterized by relative stability and economy in girls at the 5th stage of puberty. There are moderate changes in the heart rate, stroke volume and minute blood volume, and rapid recovery of these parameters to the background level, that indicates good functional capabilities of the cardiovascular system.

Keywords: *cardiovascular system, stroke volume, minute blood volume, heart rate, puberty stages, pubertal period of ontogenesis, adaptive reactions to physical activity and study load, controlled physical activity.*

Corresponding author:**Alekei Anatolevich Zverev,**

Professor,

Head University / Institute of Fundamental Medicine and Biology,

Kazan Federal University, 18 Kremlyovskaya Street,

Kazan, 420008, Russia

E-mail: krylova.alevtina@gmail.com

QR code



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INTRODUCTION:

The reform of the modern comprehensive school is accompanied by the introduction of new educational technologies into school practice, the development of innovative forms and methods of teaching. All this requires preliminary physiological studies of schoolchildren's functional capabilities, revealing the specifics of adaptive reactions at different stages of ontogenesis.

According to the age periodization, 11-16 year-old girls refer to the pubertal period of ontogenesis, the specificity of which is largely determined by the process of sexual maturation. However, this age group is very heterogeneous in terms of sexual maturity. From the pre-pubertal period to the completion of puberty, the girls gradually undergo five stages of puberty, each of which is characterized by its specific characteristics. It is known, that in the puberty period significant neuroendocrine changes, significant structural and functional changes in the cardiovascular system are occurred in the growing organism, the activity of the hormonal and mediator sections of the sympathetic adrenal system is changed, and a certain "health level" of schoolchildren is formed (1, 2, 3, 4, 9). The development of all physiological systems during this period makes high demands on the cardiovascular system, as a life support system of the organism, both at rest and under the influence of physical activity and mental workloads. The complex of loads, connected with learning activity, causing the development of long-term adaptation to its effects, has a diversified impact on the growing organism (3, 7). Dynamic physical loads significantly change the level of functioning of cardiovascular, respiratory, nervous, endocrine and other body systems of children and adolescents (5, 6, 8, 10). At the same time, the reactions to controlled physical activity are specific tests, reflecting the adaptive capabilities of life support systems. The reactivity of the cardiovascular system, regulating the processes of urgent and long-term adaptation to disturbing effects, reflects the maturity of the system in adolescents at different stages of puberty (8) and the functional capacity of the system in different periods of the academic year (3).

All of the above has determined the relevance and purpose of our investigation.

The purpose of the research: the study of adaptive reactions of the cardiovascular system of adolescent girls at different stages of puberty under the influence of controlled physical activity and depending on the period of the academic year.

ORGANIZATION AND METHODS OF THE RESEARCH

The dynamics of the cardiovascular parameters of healthy 11-16 year-old girls at different stages of puberty (stages 1-5) was studied. The stages of puberty of adolescent girls were evaluated according to the method of D. Tanner. The surveyed girls were the pupils of the secondary school of Kazan, engaged in physical training within the framework of the school curriculum. The total number of surveyed girls was 175. Changes in the stroke volume and minute volume of blood, heart rate, in response to the cycloergometric load of moderate power working capacity (50% of PWC₁₇₀) were analyzed. The reactions of the urgent adaptation of the cardiovascular system were assessed by the increase in the indices for physical activity and by the nature and duration of the studied parameters recovery after the functional test (in the 1st -7th minutes of the recovery period). The studies were conducted in the beginning (October) and at the end (April) of academic year. The girls were examined on the same days of the week and at the same time of the day (morning). Differences in the reactivity of girls' cardiovascular system in the dynamics of academic year were assessed as a result of long-term adaptation to the long-term study load. The heart rate was determined using the cardiopulmonary automated complex (AD-03M). Cardiac output (stroke volume and minute volume of blood) was investigated by rheographic method, using RPG-2-02 impedance plethysmograph. Physical working capacity was determined by the cycloergometric method, using the PWC₁₇₀ test. Controlled cycloergometric load with moderate power working capacity (50% from the individually determined PWC₁₇₀) was used as a test sample. The statistical processing of the results of the study by conventional methods of variational statistics and the correlation analysis of internal interrelations of the investigated parameters were carried out. To assess the reliability of the differences, the standard values of Student's t-test were used.

RESULTS OF THE RESEARCH:

The study of the reactivity of cardiovascular system of adolescent girls at the 1st -5th stages of puberty in response to a controlled cycloergometric load with moderate power working capacity (50% of PWC₁₇₀) allowed to reveal the differences in the degree of change in the parameters of heart rate, stroke volume (SV) and minute blood volume (MBV) in response to the test load (Tables 1, 2). Analysis of the recovery period showed, that there were some differences in the duration and nature of recovery of the cardiovascular system to the background level, depending on the stage of girls' puberty and the period of academic year.

Table 1: The parameters of heart rate (HR) in girls of the 1st-5th stages of puberty at rest and after controlled physical activity, in different periods of academic year (M ± m)

Parameter	Stage of puberty	The beginning of academic year		The end of academic year	
		Before physical activity	After physical activity	Before physical activity	After physical activity
Heart rate (bpm)	1	87.0±1.1	109.9±1.8*	75.6±1.8	98.5±2.1*
	2	81.4±1.1	104.4±2.1*	72.7±1.2	92.6±2.7*
	3	84.1±1.2	100.8±2.4*	88.9±1.2	110.7±3.3*
	4	86.3±1.3	102.6±1.7*	89.7±2.2	109.9±1.9*
	5	73.2±0.6	79.9±1.0*	69.6±2.1	82.6±1.7*

Note: * the difference with the state of rest is reliable ($P \leq 0.05$);

Table 2: The parameters of stroke volume (SV) and minute blood volume (MBV) in girls of the 1st-5th stages of puberty at rest and after controlled physical activity, in different periods of academic year (M ± m).

Parameter	Stage of puberty	The beginning of academic year		The end of academic year	
		Before physical activity	After physical activity	Before physical activity	After physical activity
Stroke volume (ml)	1	45.6±1.0	50.6±1.2*	54.3±1.2	61.2±1.5*
	2	49.8±1.1	55.5±1.6*	59.9±1.3	67.1±2.6*
	3	63.7±1.5	83.0±2.1*	56.5±2.1	79.1±3.7*
	4	66.8±1.2	93.6±1.8*	60.7±2.7	87.9±3.3*
	5	64.7±1.1	75.7±1.3*	67.6±2.0	82.5±3.1*
Mminute blood volume (l)	1	4.0±0.1	5.6±0.4*	4.1±0.1	6.0±0.5*
	2	4.1±0.1	5.8±0.7*	4.3±0.3	6.9±0.7*
	3	5.3±0.2	8.3±0.8*	5.0±0.3	8.8±0.8*
	4	5.7±0.2	9.5±0.8*	5.5±0.2	9.7±0.5*
	5	4.7±0.1	6.0±0.4*	4.7±0.1	6.8±0.2*

Note: * the difference with the state of rest is reliable ($P \leq 0.05$);

According to our data, in girls of the 1st -2nd stages of puberty, at the beginning of the academic year, there were moderate changes in the studied parameters to a functional test - the controlled physical activity. The increase in minute blood volume was on average 40.1%, the stroke volume - 10.3%, the heart rate - 24.5%. At the end of the academic year, the increase in MBV in girls of the 1st -2nd stages of puberty was on average 53.3%, SV - 12%, HR - 39%.

Attention is drawn to the fact, that in girls of the initial stage of puberty, the increase in MBV is mainly due to the chronotropic reactions of heart during all periods of the academic year. However, the most significant increase in the heart rate for dynamic load was detected at the end of the academic year.

The analysis of the dynamics of cardiac output during the recovery period showed unidirectional recovery of MBV, SV and HR parameters to the baseline, in girls of the 1st -2nd stages of puberty. The duration of the recovery period increased at the end of the academic year and was 5.5 minutes in April, relative to 4.3 minutes in October. Taking into account the moderate change in cardiac output to physical activity and its relatively rapid recovery

to the background level, the cardiovascular reactions in girls of the 1st -2nd stages of puberty can be assessed as adequate, performing in accordance with the functional capabilities of the cardiovascular system.

The conducted researches showed, that girls of the 3rd -4th stages of puberty in all periods of the academic year had the maximum reactivity of the cardiovascular system to the dynamic load. The increase in MBV at the beginning of the academic year was on average 52.5%, at the end of the year it was - 76.7%. It is noteworthy, that the increase in MBV to the test load in girls at the stage of intensive puberty is mainly due to the inotropic component of cardiac activity. The increase in SV in October was on average 38%, in April - 43%, the increase in the heart rate - was only 22 and 24%, respectively. It should be especially emphasized, that this group of girls at the end of academic year has a wave-like nature of SV and MBV recovery, the maximum duration of the recovery period was on average 6.52 min, the "negative phase" of the heart rate recovery, characterized by a decrease in the value of this indicator, was below the baseline. The observed changes allowed to characterize the adaptive reactions of girls at the 3rd -4th stages of

puberty as uneconomic to dynamic loads, reflecting the intense functioning of the cardiovascular system and indicating the reduced functional capacity of the girls' system at the end of the academic year. The observed regularity is probably not only the consequence of the influence of neuroendocrine rearrangement of the girl's organism in this period, but also the influence of external conditions (study loads, training regimes, school hypodynamia, static load), which have an adverse effect on the body, causing intense function of cardiovascular system (3).

In girls of the 5th stage of puberty, the reactions of urgent adaptation to the controlled cycloergometric load during the academic year are characterized by relative stability and economy. There are moderate changes in the parameters of MBV, SV, HR, and their rapid recovery to the background level. The priority of inotropic component of cardiac activity is revealed, which indicates good functional capabilities, relative maturity of the cardiovascular system, adequate reactions to the testing load in girls of the final stage of puberty.

To assess the internal relations of the cardiovascular system parameters of adolescent girls, a correlation analysis was carried out between the indices of heart rate, stroke volume and minute blood volume. The correlation coefficient "r" was determined. Its value varied from +1 to -1. It is known, that the stronger the bond, the greater the value of correlation coefficient. We evaluated the strength of the correlation between MBV and CV, MBV and HR, SV and HR in girls at different stages of puberty before and after the controlled dynamic load in different periods of the academic year.

The conducted correlation analysis allowed to reveal the change in the strength of all available correlations between the investigated parameters after the controlled physical load. The nature of the changes varied in girls of different stages of puberty.

In girls of the 1st -2nd stages of puberty adaptation of the cardiovascular system to physical activity was accompanied by a significant increase in the strength of the correlation MBV - HR. The coefficient of correlation after the load at the beginning of academic year increased to +0.82, compared to +0.68 in the state of rest. At the end of the academic year, the strength of the correlation MBV - HR was on average +0.89. At the same time, in this group of girls there was no increase in the strength of the correlation MBV - SV to the functional test, compared to the background level. The correlation coefficient ranged from +0.62 to +0.63. The observed tendency confirms the priority of the chronotropic component of cardiac activity in ensuring the minute blood volume and shows a fairly good level of adaptive cardiovascular reactions in girls of the first stage of puberty.

On the contrary, in girls of the 3rd -4th stages of puberty in response to physical activity during all periods of the academic year, an increase in the strength of the correlation MBV - SV (from $r = +0.78$ to $r = +0.90$) and weakening of the correlation MBV - HR (from $r = +0.65$ to $r = +0.53$) were revealed. This fact confirms the leading role of SV in the provision of MBV in girls at the stage of intensive puberty. The observed dynamics is consistent with the age-related trend of cardiac rhythm decrease and increase in the stroke volume in the process of adolescence growing.

In girls of the final stage of puberty, in response to the controlled physical activity, there was also the strengthening of the correlation between the parameters of stroke volume and minute blood volume. The strength of the correlation MBV - SV after physical activity increased at the beginning of the academic year from +0.83 to +0.92, at the end of the year it increased from +0.85 to +0.94. The revealed dynamics confirms the increase in the influence of the inotropic component of cardiac activity with age. It is noteworthy, that in girls of the 5th stage of puberty, there is a negative correlation of SV-HR ($r = -0.65$). Consequently, a high value of HR acts as a deterrent in the formation of the stroke volume.

It should be noted, that in girls of the final stage of puberty, the correlations between stroke volume and minute blood volume before and after physical activity is characterized by high strength and relative stability during the academic year. This is assessed as a positive phenomenon, indicating both the favorable response of the cardiovascular system to the functional test, and the good tolerability of the study load in adolescent girls at the 5th stage of puberty.

DEDUCTIONS

The results of our investigations of changes in the heart rate, stroke volume and minute blood volume of adolescent girls at different stages of puberty, under the influence of dynamic load, during the academic year, showed the priority of the chronotropic component of cardiac activity in the adaptive reactions of the cardiovascular system in girls of the 1st -2nd stages of puberty, and the inotropic component - in girls of the 3rd -5th stages.

It was revealed, that in girls at the stage of intensive puberty (stages 3- 4) there is a tense adaptation of cardiovascular system to the dynamic load of moderate power, manifested in the maximum changes of the cardiac output, in the wavy nature of the recovery of stroke volume and minute blood volume, "negative phase" of the heart rate recovery, maximum duration of the recovery period. Tense adaptation is more pronounced at the end of the academic year, when the impact of study load and distress on adolescent girls is the greatest.

The results of our research may be of interest to specialists in the field of age and sports physiology, coaches of children's sports schools, school teachers and teachers of physical training. When planning sport load, work load, educational process of adolescents, the intense functioning of the cardiovascular system of adolescent girls at the 3rd - 4th stages of puberty should be taken into account.

CONCLUSIONS:

Priority of the chronotropic component of cardiac activity is revealed in girls of the 1st -2nd stages of puberty in adaptive reactions of the cardiovascular system to the controlled physical activity; girls of the 3rd -5th stages have the priority of the inotropic component of cardiac activity.

Girls of the 3rd -4th stage have a tense adaptation of the cardiovascular system to the controlled physical activity, which is more pronounced at the end of the academic year.

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