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ARTICLE

HORMONAL REACTIONS IN CHILDREN DURING DYNAMIC PHYSICAL LOAD

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ABSTRACT

One of the key functions of the catecholaminergic hormonal system or sympathetic-adrenal system (SAS) is the mobilization of the body's energy resources during muscle activity. The mechanisms of adaptation of children to dynamic physical activity differ in many ways from those in adults. Adaptation occurs mainly due to vegetative reactions, while the mobilization readiness of the SAS is insufficient. Physical activity is an integral part of the life of children and adolescents, however, at present, modern schoolchildren are dominated by static posture, and motor activity is reduced. The article describes the results of a study of the SAS reaction of children aged 7-15 to dosed physical activity subject to the age, gender, and the initial autonomic tone (IAT). Fluorometry was used to measure the levels of adrenaline (A), norepinephrine (NA), DOPA, and dopamine (DA) in the urine portion before and after exercise. The initial autonomic tone (IAT) was measured by the histogram obtained by cardiointervalography on an automated REACARD device. The conclusion about IAT was carried out according to the parameters of amplitude mode (AMo), variational range (ΔX) and regulatory mechanism stress index (SI). As a functional test, we used a 1.5 W bicycle stress test, calculated per 1 kg of the subject's body weight. An analysis of the level of excretion of A, NE, DA, and DOPA at a state of relative rest and after a bicycle stress test revealed that the nature of urgent adaptation of SAS in schoolchildren varies with age, and depends on the gender and autonomic tone of children. Differences between children with sympathetic and vagotonic initial autonomic tones were revealed. Regardless of age, the reaction of sympathotonic children is more adequate, indicating an emergency mobilization of the body's energy resources. Vagotonic children at the age of 9.10 and 14.15 years showed a sharp decrease in the level of excretion of NE, DA, and DOPA, despite the low preload values. It is shown that the period of the most stable physical performance of children is the age of 9.10 years for boys and 7.12 years for girls, which allows us to consider it as the most favorable for the beginning of an intensive training process. It is shown that moderate and balanced SAS reactions are a prerequisite for sustainable physical performance of school-age children.

KEY WORDS
sympathetic-adrenal system, children's physical activity, initial vegetative tone

INTRODUCTION

The adaptation mechanisms of children to physical activity are very different from those in adults [1,2]. An exceptional role in the nervous and humoral regulation of adaptation processes is played by SAS, one of the main functions of which is the mobilization of energy resources during muscular activity. Adaptation-trophic effects of the sympathetic nerves are transmitted to the skeletal muscles due to the mediator of norepinephrine (NE) adrenergic plexuses of blood vessels [3,4]. A short-term dosed physical activity causes activation of the hormonal link and an increase in adrenaline (A) as an "anxiety hormone", and long-term and moderate exercise cause an increase in NE as a "homeostasis hormone" [5]. Of great importance for assessing the reserve capabilities of SAS is the analysis of the shift of catecholamine precursors (CA). According to existing ideas, an increase in the excretion of A and NE against the increase in the level of dopamine (DA) and DOPA may indicate the mobilization of SAS reserves [6]. An adverse reaction is when an increase in CA is not accompanied by a corresponding increase in DA and DOPA. SAS reactivity can be widely used to assess the functional capabilities of this system in children at different ages and at different periods of education [4,5]. There is no doubt that the tone of the autonomic nervous system (ANS) affects the activity of the catecholaminergic system [7]. A functional test sample in the form of a dosed physical load allows us to judge the reserve capabilities of the regulatory system. The response of the body to the effect of a gradual load is regarded as reactivity [6], that is, a temporary characteristic of functional shifts, the direction of which depends on the degree of fitness for a given external stimulus. Physical activity causes the activation of SAS. However, quantitative and qualitative shifts in the excretion of spacecraft depend on the age of the children, the degree of fitness, the severity of psycho emotional stress, and the characteristics of the nervous system of the subjects [7].

The study showed that the proportion of metabolic reactions associated with muscle activity in children is relatively lower. Adaptation of an organism to physical activity occurs mainly due to vegetative reactions [8]. Moreover, the mobilization readiness of the SAS at the prelaunch stage is insufficient.

Against the background of a large number of scientific studies, the issues of age-gender characteristics of SAS reactions to physical dynamic loads, which are an integral part of the life of children and adolescents, have been little studied. Moreover, the assessment of the nature of the urgent adaptation of the SAS of the child's body is carried out, as a rule, without taking into account the initial state of the central and peripheral parts of the ANS. It is also known that vegetative tone is one of the most important parameters that reflect the direction of adaptive rearrangements during muscular activity [9,10].

The objective of this study was to study the tonic effects of the ANS on the adaptation of SAS to gradual physical activity in schoolchildren.

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MATERIALS AND METHODS

The experiment involved 130 children of 7-15 years old of both sexes, of the main health group. The level of A, NE, DOPA, and DA was fluorometrically [11] recorded in a portion of urine before and after exercise. The initial autonomic tone (IAT) was determined using the histogram obtained by the method of cardiointervalography on the automated REACARD complex. The conclusion about IAT was carried out according to the parameters of amplitude mode (AMo), variational range (ΔX) and regulatory mechanism stress index (SI) [10,12]. As a functional test, we used a 1.5 W bicycle stress test, calculated per 1 kg of the subject's body weight. Descriptive statistics and t-test were used. Written consent from the subjects or parents was taken and the study was approved by the Kazan University ethical committee.

RESULTS

It was found that autonomic tone affects the hormonal reactions of the body, the nature of shifts in gradual physical activity depends on the age of the children. In 7-year-old schoolchildren with a predominance of sympathetic influences, the level of A and NE increases from 25.30% to 33.00%, and DOPA and DA - from 19.13% to 4.93%. In vagotonic boys, on the contrary, the release of DA decreases against the background of stable values of A and NE (Tab. 1). In the normotonic state, the most significant shift is noted in relation to A, amounting to 6.50 ng/min ($p < 0.05$). An increase is also observed in the excretion of NE from 15.33±1.11 ng/min to 20.16±2.01 ng/min ($p < 0.05$). This is accompanied by an adequate increase in dopamine levels by 33.81 ng/min ($p < 0.05$). That is, the normotonic variant of IAT is the most balanced variant of autonomic regulation that characterizes favorable changes in SAS. The 7-year-old vagotonic boys show no significant shifts in CA excretion with a decrease in the DA level by 17.20 ng/min. The asthenization syndrome of the child's body and the lack of formation of adaptation mechanisms to dynamic loads in 7-year-old boys are likely to manifest.

With age, the SAS reaction changes. In vagotonic children aged 8 years, it is more balanced, with an increase in excretion of A and NE ($p < 0.05$) and an increase in DA (11.25%).

Table 1: The content of catecholamines and DOPA in the urine of 7-year-old boys and girls under the influence of a bicycle stress test with a different initial vegetative tone (M±m)

No.		IVT	Indicators							
			Dopamine, ng / min		DOFA, ng / min		Adrenalin, ng / min		Norepinephrine, ng / min	
			before	after	before	after	before	after	before	after
boys	1	S	139.94±5.84	165.88±8.01 ∑	14.84±1.69	16.00±1.94	8.11±0.56	10.71±0.92	18.55±1.16	23.26±2.24 ∑
	2	No.	183.81±8.68	216.47±10.12 ∑	19.10±1.85	20.35±1.94	8.33±0.21	14.83±0.98 α»	15.33±1.11	20.16±2.01 ∑
	3	V	165.30±7.37	148.10±4.65	15.45±1.34	15.28±1.47	7.96±0.59	7.92±0.64	15.94±1.02	15.09±0.96
girls	1	S	119.42±4.37	168.59±6.62 ∑	12.50±1.12	12.59±1.19	7.66±0.16	11.05±0.96 α»	16.81±1.83	19.77±1.91
	2	No.	140.20±60.01	203.35±12.97 α»	13.67±1.62	14.31±1.65	7.34±0.23	12.62±0.88 α»	13.72±1.40	20.79±2.00 α»
	3	V	154.37±7.34	176.87±9.02 ∑	20.72±1.88	23.94±2.01	7.16±0.49	11.51±0.84 ∑	14.81±1.12	20.66±1.12 ∑

Note: the differences are significant in comparison with the state at rest: «●» $p<0.05$; «●●» $p<0.01$

Table 2: The content of catecholamines and DOPA in the urine of 9-year-old boys and girls under the influence of a bicycle stress test with a different initial vegetative tone (M±m)

No.		IVT	Indicators							
			Dopamine, ng / min		DOFA, ng / min		Adrenalin, ng / min		Norepinephrine, ng / min	
			before	after	before	after	before	after	before	after
boys	1	S	127.30±6.96	123.10±10.97	11.76±1.00	11.04±1.22	6.26±0.42	7.47±0.59	15.31±1.61	18.83±1.82
	2	No.	213.99±11.34	214.02±12.05	15.64±1.36	16.02±1.48	7.98±0.64	10.72±0.90 ∑	16.62±1.63	20.40±2.02
	3	V	193.27±10.38	254.13±14.35 α»	13.32±1.27	14.87±1.40	7.33±0.40	11.74±0.86 ∑	15.50±1.76	28.83±2.00 α»
girls	1	S	161.80±7.83	132.86±5.25 α»	11.64±1.01	11.96±1.17	10.02±0.92	10.84±0.81	21.80±1.94	22.02±1.66
	2	No.	163.75±6.98	193.87±9.62 ∑	14.62±1.32	15.04±1.48	7.24±0.53	8.16±0.67	14.40±1.15	20.17±1.86 ∑
	3	V	124.05±3.69	120.65±3.60	13.81±1.22	13.04±1.19	7.44±0.62	5.76±0.34 ∑	19.21±1.61	16.55±1.24

Note: the differences are significant in comparison with the state at rest: «●» $p<0.05$; «●●» $p<0.01$

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A high level of physical performance was found in boys aged 9 and 10 years, which is most pronounced in the group of vagotonics: the level of excretion of NE increases by 53.00% and 71.84%, and A - by 62.01% and 85.94% ($p < 0.05$) with an increase in DA (33.64%). So, in 9-year-old boys, the SAS reaction to dosed physical activity is more balanced (Tab. 2), which is especially pronounced in the normotonic and vagotonic state. Normotonic patients have a moderate increase in A and NE by 2.74 ng/min and 3.78 ng/min ($p < 0.05$) against the background of stable indices of predecessors. Even more effective is the reaction of vagotonic boys, with a significant increase in A and NE excretion by 53.00% and 62.01% ($p < 0.01$) and ($p < 0.05$) accompanied by an increase in DA excretion by more than 35% ($p < 0.05$).

An increase in the adaptive capabilities of SAS is observed in boys aged 12 and 13 years and is expressed more significantly in the normotonic and vagotonic state, when there is an increase in the excretion of A and NE in response to physical activity in the range from 35.20% to 59.65% ($p < 0.05$). However, in sympathotonic boys, the shift in NE does not exceed 16.25%.

The puberty neuro-endocrine transformations typical of adolescents aged 14 and 15 [13,14] change the nature of adaptive reactions (Tab.3). Thus, sympathotonics aged 14 years showed a sharp jump in NE excretion by 10.96 ng/min ($p < 0.05$) in the absence of a significant shift in DA excretion and a tendency toward a decrease in DOPA. Vagotonics, on the contrary, have a decrease in NE excretion by 10.25 ng/min ($p < 0.01$), while the excretion of DA decreases from 189.99±9.96 ng/min to 162.37±8.26 ng/min. That is, the depletion of SAS reserves explains the absence of a shift in CA excretion. Only in boys in a state of eutonia the reaction of urgent adaptation of SAS is considered balanced - an increase in the excretion of NE ($p < 0.05$), a moderate shift of A against the background of a tendency toward an increase in predecessors. A sharp decrease in the reserve of SAS is observed under sympathicotonia - NE excretion at the age of 15 years increases to 80.30%, and the DOPA level decreases ($p < 0.05$). In vagotonics, signs of body asthenization are observed - a decrease in NE by 5.01 ng/min ($p < 0.05$) with a decrease in DA ($p < 0.05$).

In girls, unlike boys, at the age of 7 years, the reaction of the adrenal glands is more adequate. Regardless of IAT, there is an increase in A and NE in the range from 45.25% to 72.34%, which is accompanied by an increase in DA by 45.04%. Thus, in sympathotonic girls, the bicycle stress test causes an increase in A excretion by 3.94 ng/min ($p < 0.01$), while the DA level increases from 119.42±4.37 ng/min to 168.59±6.62 ng/min. In normotonic girls, the reaction is balanced with respect to all parts of the CA biosynthesis. The jump in the excretion of A and NE by 5.28 ng/min and 7.07 ng/min ($p < 0.05$) is combined with an equally significant increase in DA - from 140.20±60.01 ng/min to 203.35±12.97 ng/min ($p < 0.01$). In vagotonics, the SAS reaction is smoother but equally favorable - an increase in A and NE in the range from 3.24 ng/min to 6.25 ng/min ($p < 0.05$) is accompanied by a significant increase in DA ($p < 0.01$) against a moderate positive shift in DOPA levels.

A decrease in compensatory reactions is observed at the age of 8 years when the sympathetic and normotonic group has no positive shift in excretion of A and NE, and the release of DA decreases by 9.35%. Positive dynamics in the excretion of catecholamines is observed only in schoolgirls with a vagotonic IAT. The normotonic 9-year-old girls show sufficient functional reserves of SAS - the DA level increases by 30.21 ng/min ($p < 0.05$) with increased excretion of NE ($p < 0.01$) and stabilization of A and DOPA levels, which is not the case for the sympathonic and vagotonic girls. In the first group, the shift of catecholamines is absent, and the DA content significantly decreases - by 28.94 ng/min ($p < 0.01$), that is, the low level of reserve capabilities of SAS explains the absence of shifts in the CA excretion as the reaction to standard physical activity. The vagotonic 9-year-old girls clearly show signs of a decrease in the adaptive capacity of the studied neurohumoral regulatory system: there is a decrease in A excretion ($p < 0.05$), a tendency toward a decrease in NE, and a lack of shift in the content of precursors.

Table 3: The content of catecholamines and DOPA in the urine of 14-year-old boys and girls under the influence of a bicycle stress test with a different initial vegetative tone (M±m)

No.		IVT	Indicators: Dopamine, ng / min		DOFA, ng / min		Adrenalin, ng / min		Norepinephrine, ng / min	
			before	after	before	after	before	after	before	after
boys	1	S	160.70±8.14	177.32±8.98	23.66±1.22	22.92±1.02	8.26±0.44	10.32±0.66	24.01±1.83	34.96±2.12
										∑
	2	No.	180.63±10.23	203.92±12.34	24.40±1.28	25.66±1.34	8.63±0.42	9.60±0.74	19.66±1.77	29.94±1.92
										∑
	3	V	189.99±9.96	162.37±8.72	20.37±1.00	20.00±1.12	8.96±0.40	11.91±0.72	23.88±1.86	13.34±1.28
				∑				∑		α»
girls	1	S	169.93±7.42	172.28±8.01	20.25±1.18	21.32±1.20	6.96±0.21	10.34±0.70	20.90±1.69	30.66±1.92
								∑		α»
	2	No.	±	±	±	±	±	±	±	±
	3	V	190.04±10.32	157.16±5.12	23.60±1.46	23.04±1.30	8.84±0.62	7.66±0.78	17.00±1.00	17.63±1.14

Note: the differences are significant in comparison with the state at rest: «●» $p<0.05$; «●●» $p<0.01$

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Normotonic 12-year-old girls are a group of children with the most favorable SAS reaction. After the dynamic load, a moderate but significant increase in A and NE excretion occurs - from 35.90% to 50.65%.

At the age of 13-15 years, the adaptive reactions of the nervous and endocrine systems of girls decrease again, which may be due to the functional tension of the hypothalamic-pituitary system in adolescence [15]. Thus, in sympathotonic girls, despite the relative increase in indices at rest, the shift in NE during the load is greatest, and there is no positive dynamics of the predecessors. A decrease in the reserve capacity of SAS is also observed in vagotonics - against the background of a low preload level, negative shifts are observed in the excretion of NE (14 years) and DA (a decrease of 18.00%). That is, physical activity is stressful for girls aged 13-15 years.

CONCLUSION

The obtained results allow us to conclude that favorable SAS reactions to gradual physical activity are observed in boys of 9 and 10 years old, and in girls of 7 and 12 years old - an increase in excretion of A and NE is accompanied by an increase in DA and DOPA. The study showed that moderate and balanced SAS reactions are a prerequisite for the sustainable physical performance of school-age children. The most favorable period for the beginning of an intensive training process for boys is the age of 9 and 10 years, and for girls - 7 and 12 years.

CONFLICT OF INTEREST
There is no conflict of interest.

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