

# The Role of Catecholamins in the Regulation of Children's Body Hemodynamic

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**Abstract---** *The catecholamine system stands out among other hormonal systems by its participation in the regulation of hemodynamic functions. In children, the level of hormones and mediators is not constant, which explains the lack of formation of the mechanisms of regulation of the circulatory system. Long-term static postural stress of the child at school and home causes rapid muscle fatigue and mental stress, which does not exclude vegetative dysfunctions and abnormalities in the cardiovascular system (CVS). Conducted a comprehensive study of the state of hemo dynamics and adrenal glands in children 7 years old, an analysis of the correlations between their parameters. Daily and portioned urine was collected in spring and autumn, and the levels of adrenaline (A), norepinephrine (NA), dopamine (DA) and DOPA were recorded by fluorometry. The state of the circulatory system was studied by indicators of cardiac output - stroke volume of blood (CLC) and minute circulation - IOC. Thoracic rheoplethysmography with an analog-to-digital converter was used. Peripheral circulation was recorded by analysis of blood pressure (systolic, diastolic and mean hemodynamic blood pressure (SBP), (DBP) and (SRS). The method of pair correlation was used to study the interdependence of indicators of the endocrine system and the circulatory system. The relationship of the hormones of the adrenal medulla and the parameters of the CVS of the child's body is shown. This was most clearly manifested in the state of the functional stress of the body, a variant of which was the dosed static load. A relationship was found between the hemodynamic reaction and the level of excretion of catecholamines (CA) and DOPA in the post-isometric period. Isometric muscle tension of the upper limb causes an increase in the tone of peripheral vessels and a parallel increase in NA in children of 7 years of age. At the same time, at the end of the school year, there is a negative dynamics in the excretion of A, NA, and DA, accompanied by a decrease in the CRF and IOC in the recovery period. A decrease in the activity of adrenergic influences on the pumping function of the heart is indicated by a break in the correlation bonds of A and NA with UOK and IOC. Thus, the study allowed us to identify the relationship between hemodynamic parameters and the level of catecholamine excretion in the post-isometric period in children 7 years old. The effect of NA on the state of peripheral vascular tone has been proven, unidirectional changes in the level of NA excretion and DBP values, total peripheral vascular resistance (OPSS) after static muscular effort have been established.*

**Keywords---** *Catecholamines, Cardiovascular System, Isometric Load, Children 7 Years Old.*

## I. INTRODUCTION

It is known that catecholamines regulate the functioning of the heart and blood vessels (Sitdikov & Zefirov, 2006). An increase in the pumping function of the heart under the action of A was found; it also enhances

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chronotropic reactions, which generally increases systemic blood pressure (Yanagihara et al., 2005). Fundamental is glycolysis in the myocardium, namely its increase. The opposite effect on the heart is exerted by NA, it reduces the CRF in severe bradycardia. So the reflex effect of n is manifested vague to the heart muscle. The precursor of NA is DA, which refers to the mediators of the nervous system. The effect of DA is similar to the effects of A and NA. The precursor of DA - DOPA, characterizes the potential capabilities of the catecholaminergic system (Yanagihara et al., 2005). It is known that A, found in urine, has a predominantly adrenal origin, indicates the state of the hormonal link, the sympathetic regulatory system. The source of NA in the body is the end of the sympathetic nerves, it can be attributed to the mediator link of the sympathetic department of the autonomic nervous system (Sitdikov&Zefirov. 2006). There is no doubt that the amount of CA with the functional stress of the child's body - psychoemotional loads, muscle activity and physical inactivity (Krylova et al., 2018). Attempts to connect the activity of the adrenal medulla with the dynamics of CVS indicators and, thus, use these relationships as indicators of the stress state of children is one of the promising directions in the development of age-related physiology.

In children, the level of hormones and their mediators is variable. The influence of CA on the functions of the CVS of the body, its adaptive capabilities are not well understood. There is information about shifts in the excretion of CA and DOPA under school conditions, under the influence of dosed physical activity (Krylova et al., 2018), as well as data from a parallel analysis with hemodynamic parameters (SHAikhelislamova et al., 2018). The child's prolonged postural stress at school causes rapid fatigue, autonomic dysfunctions and deviations in the CVS are not excluded (Robson & Fluck, 1978; Nakamoto & Matsukawa, 2006). Noting significant shifts in the indices of the leading functional systems of the body, the question is raised about the correspondence of the intensity of training loads to the physiological capabilities of the body of children. The preservation of the mental and physical performance of children under conditions of a large volume of loads is due to the pronounced stress of functions and the breakdown of adaptation mechanisms. It is necessary to introduce measures to improve the motor regime of schoolchildren as one of the ways to prevent diseases of the nervous system and circulatory system of children and adolescents. The study of correlations will make it possible to judge the role of CA in providing hemodynamic effects, which can most clearly manifest itself in a state of physical stress and stress. Based on the urgency of the problem, we formulated the goal of the study: a comprehensive study of the state of hemodynamics and excretion of catecholamines, as well as the correlations between them in 7-year-old children under conditions of relative rest and after local static load.

## II. METHODS

Schoolchildren of the 1st grade were invited to the experiment, 7 years old - 42 people. Daily and portioned urine was collected in spring and autumn, and the levels of adrenaline (A), norepinephrine (NA), dopamine (DA) and DOPA were recorded by fluorometry. The state of the circulatory system was studied by indicators of cardiac output - stroke volume of blood (CLC) and minute circulation - IOC.

Thoracic rheoplethysmography with an analog-to-digital converter was used. Peripheral circulation was recorded by analysis of blood pressure (SBP, DBP, and SRS). Isometric contraction of the muscles of the forearm was regarded as a local static load. A manual dynamometer was used, the load was set for 1 minute and 5 minutes of the

recovery period. The method of pair correlation was used to study the interdependence of indicators of the endocrine system and the circulatory system.

### III. RESULTS

A parallel examination of hemodynamic and biochemical parameters, an analysis of the correlations between them made it possible to judge the role of CA in providing hemodynamic effects in children. This was most clearly manifested in a state of functional tension of the body. Considering that static loads act as a provoking factor in the development of cardiovascular diseases (Robson & Fluck, 1978; Shaikhelislamova et al., 2016), we analyzed the relationship between the level of excretion of CA and CVS parameters in the post-isometric period. The sympathetic nerve centers are involved in the regulation of the adaptation of the CVS to static loads. There is a spasm of peripheral vessels and a reflex response to it, which in schoolchildren changes during the year (Tab 1.). In October, the CVS reaction is provided by increasing vascular tone: DBP in the first-minute increases by 7.64 mm Hg. ( $p < 0.01$ ) and during restitution does not reach

Tab. 1: Hemodynamic Response to Local Static Load in Boys of 7 Years in Different Periods of the School Year

Condition	Indicators							
	Heart rhythm, beats/min	Systolic pressure, mmHg	Diastolic pressure, mmHg	Mean pressure, mmHg	Systolic ejection, ml	Minute blood flow, l	OPSS, $\text{din} \cdot \text{s}^{-1} \cdot \text{cm}^{-5}$	
<b>October</b>								
Guiescency	105.10 ± 1.97	111.33 ± 1.26	66.33 ± 1.58	85.25 ± 1.68	42.60 ± 1.04	4.47 ± 0.45	1598.96 ± 64.02	
Recovery	1 min	** 95.27 ± 1.96	110.00 ± 1.33	** 74.00 ± 1.24	89.12 ± 1.14	** 35.17 ± 1.67	3.35 ± 0.52	**2025.15 ± 98.37
	3 min	* 98.48 ± 1.68	108.00 ± 1.62	68.00 ± 1.50	84.80 ± 1.84	** 35.69 ± 1.62	* 3.51 ± 0.47	* 1930.83 ± 84.13
	5 min	** 93.78 ± 1.86	** 101.66 ± 0.90	68.33 ± 1.90	82.32 ± 1.79	38.64 ± 1.46	3.68 ± 0.47	1787.77 ± 73.28
<b>April</b>								
Guiescency	90.18 ± 1.75	108.50 ± 1.47	71.00 ± 1.20	86.75 ± 1.32	25.77 ± 1.09	2.33 ± 0.39	2690.36 ± 229.97	
Recovery	1 min	99.00 ± 1.87	111.00 ± 2.69	68.00 ± 1.63	84.38 ± 1.45	* 22.03 ± 1.35	2.00 ± 0.30	* 2446.57 ± 216.20
	3 min	96.00 ± 1.47	109.00 ± 1.78	73.00 ± 0.45	90.12 ± 0.30	* 20.82 ± 1.34	2.00 ± 0.35	**4000.08 ± 278.15
	5 min	92.31 ± 1.02	110.00 ± 0.78	70.00 ± 0.63	90.70 ± 1.08	* 20.31 ± 1.16	1.74 ± 0.32	**3999.91 ± 391.45

Note: reliability at "\*"  $p < 0.05$ ; "\*\*\*"  $p < 0.01$

Tab. 2: The Effect of the Isometric Load on the Excretion of CA and DOPA in Children 7 Years Old

Item No.	Periods of the school year	Indicators							
		Dopamine, ng / min		DOFA, ng / min		Adrenalin, ng / min		Norepinephrine, ng / min	
		before	after	before	after	before	after	before	after
1	October	124.33 ± 4.73	161.25 ± 8.62	22.17 ± 1.33	21.85 ± 2.17	8.49 ± 0.78	9.82 ± 0.59	20.66 ± 1.35	28.82 ± 1.00
		●●						●	
2	April	157.27 ± 7.34	137.53 ± 5.62	13.94 ± 1.62 M	15.84 ± 1.47	14.83 ± 0.42	11.03 ± 0.46	16.03 ± 1.36	13.49 ± 1.37
		●				●			

Note: the differences are significant compared with the rest "●"  $p < 0.05$ ; "●●"  $p < 0.01$ .

Pre-loading values, stabilizing by 3 minutes. OPSS, which at rest is  $1598.96 \pm 64.02 \text{ din} \cdot \text{s}^{-1} \cdot \text{cm}^{-5}$  in the first minute after exercise increases by  $426.19 \text{ din} \cdot \text{s}^{-1} \cdot \text{cm}^{-5}$ , which is mathematically significant in the range ( $p < 0.01$ ). In the third minute of recovery, the SPSS values also exceed the preload level ( $p < 0.05$ ). By the fifth minute of restitution, this parameter is  $188.81 \text{ din} \cdot \text{s}^{-1} \cdot \text{cm}^{-5}$  more than at rest. In the recovery period, an increase in vascular tone (SRS, DBP, OPSS) by a significant amount is recorded. At the same time, cardiac output decreases, amounting to  $42.60 \pm 1.04 \text{ ml}$  at rest, the CRF decreases by  $7.43 \text{ ml}$  by the first and third minutes of recovery. In the fifth minute, it rises slightly ( $38.64 \pm 1.46 \text{ ml}$ ), without reaching, however, pre-loading values. A similar picture is observed with respect to the IOC. Being at a level of  $4.47 \pm 0.45 \text{ L}$  at rest, the IOC decreases to  $3.35 \pm 0.52 \text{ L}$  ( $p < 0.05$ ) and  $3.51 \pm 0.41 \text{ L}$  in the first and third minute of recovery. This indicator remains at the same level by the fifth minute of restitution. A decrease in cardiac output after static tension of the muscles of the forearm may be associated with spasm of blood vessels in the limbs and a decrease in venous return (Robson & Fluck, 1978). Post-exercise bradycardia is noteworthy. So, heart rate compared with rest is reduced by  $9.83 \text{ beats/min}$  ( $p < 0.01$ ) and remains at this level until the fifth minute of recovery. Probably, a reflex increase in the influence of n is noted. vagus with a jump in sympathetic influences. A decrease in cardiac output causes a progressive decrease in SBP, which at rest is  $111.33 \pm 1.26 \text{ mm Hg}$ , and at the third and fifth minutes of recovery -  $108.00 \pm 1.62 \text{ mm Hg}$ , and  $101.66 \pm 0.90 \text{ mm Hg}$ , respectively.

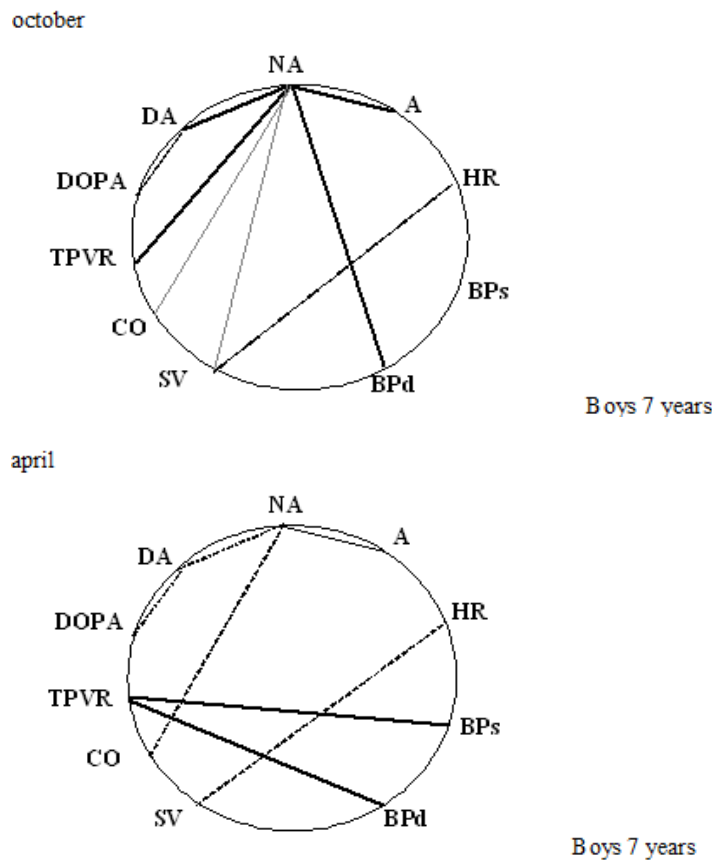


Fig. 1: Correlation between Hormonal and Hemodynamic Parameters after Local Static Load

Note: positive, weakly positive, ----- negative connection

A peripheral spasm of blood vessels in parallel with an increase in NA (Tab. 2) proves that this particular hormone is a regulator of vascular tone. Thus, an analysis of CA excretion in October showed that the most significant changes are observed with respect to NA, which sharply increases to  $28.82 \pm 1.00$  ng/min ( $p < 0.05$ ), while at rest it does not exceed  $20.66 \pm 1.35$  ng/min. DA excretion increases adequately - by 36.92 ng/min compared with resting conditions ( $p < 0.01$ ), which indicates the presence of reserve capacity of the adrenal glands in children at this stage of adaptation to static loads in school. Changes in excretion of A and DOPA are minor, although they indicate an upward trend. There is a strong positive relationship between OPSS - NA, DBP - NA, and a weak correlation - IOC - NA, OOK - NA ( $r = 0.25$ ). The effect of NA on vascular tone in various parts of the bloodstream on arterial and venous pressure is determined by impulses coming from the anterolateral part of the hypothalamus. The vasoconstrictor effect coming from the hypothalamus is supported by a sympathetic tone of adrenoreceptors on the periphery and continuously secreted by NA. A conflict situation may arise between A and NA in the periphery due to the weak vasoconstrictor action of A (Sitdikov & Zefirov, 2006). Catecholamines have a direct effect on coronary blood flow. At the same time, the direct effect of NA on the coronary vessels is differentiated from the side effect on blood pressure (Yanagihara et al., 2005). That is, the fact of the influence of CA on cardiac activity is indisputable - on the force of myocardial contraction, on the CRF and IOC, as well as on the various phases of its systole.

A different picture in the state of hemodynamics is observed in schoolchildren in April (Tab. 1). There is a tendency to increase heart rate by 8.82 beats/min in the first minute of recovery. Moreover, blood pressure indicators are generally stable - the SBP is in the range from  $108.50 \pm 1.47$  mm Hg. up to  $111.00 \pm 2.69$  mm Hg; DBP does not exceed  $73.00 \pm 0.45$  mm Hg, and SRS -  $90.12 \pm 0.30$  mm Hg. The most significant changes are in the indicators of UOK and OPSS. Thus, in comparison with dormancy ( $25.77 \pm 1.09$  ml), CRI decreases by 3.74 ml ( $p < 0.05$ ) by the first minute and by 5.46 ml by the fifth minute of recovery ( $p < 0.05$ ). At the same time, the OPSS values sharply increase - by  $1310.00 \text{ din} \cdot \text{s}^{-1} \cdot \text{cm}^{-5}$  and  $1309.91 \text{ din} \cdot \text{s}^{-1} \cdot \text{cm}^{-5}$  at the third and fifth minutes of restitution, respectively ( $p < 0.01$ ). Probably, blood pressure is maintained due to spasm of the peripheral vessels, as the rate of OPSS increases significantly ( $p < 0.05$ ). The IOC is at a relatively stable level. During restitution after isometric stress, there is a decrease in the SOC and IOC in the range from 18.50% to 20.15% ( $p < 0.05$ ), while the chronotropic reaction is sharply enhanced and remains so until the end of the experiment. On the basis of what we can say that signs of fatigue appear in the CVS (Shaikhelislamova et al., 2015; Monasterio et al., 2016). Such a hemodynamic reaction is accompanied by a decrease in the hormonal activity of the adrenal glands - the level of adrenaline excretion decreases by 16.94%, which in absolute terms is 3.80 ng/min ( $p < 0.05$ ); NA- 10.03% ( $2.54 \text{ ng} / \text{min}$ ). The depletion of the reserve capabilities of the adrenal medulla is evidenced by a decrease in the excretion of DA, which is a precursor in the CA biosynthesis chain, from  $157.27 \pm 7.34 \text{ ng} / \text{min}$  to  $137.53 \pm 5.62 \text{ ng} / \text{min}$ , which is mathematically significant and amounts to 12.25% ( $p < 0.05$ ). A parallel increase in DOPA is insufficient, therefore, it does not provide an adequate increase in CA. The adaptive capacity of the adrenal glands is reduced, as evidenced by the lack of interconnection in the biosynthesis chain of catecholamines (Fig. 1) A - NA ( $r = 0.20$ ), NA-DA ( $g=0.40$ ), DA - DOPA ( $g = - 0, 32, p < 0.05$ ), as well as the gap in the correlations between the IOC and UOK, CAD-UOK and the inverse relationship between heart rate and UOK ( $g = - 0.69, p < 0.05$ ).

A decrease in the sympathetic effects on the contractile function of the heart is indicated by a break in the correlations between UOK - A, IOC - A, NA - UOK (Al-Khelaifiet al., 2018).

The data obtained indicate the presence of functional condition between the studied parameters of CVS and adrenal glands at rest, during and after static muscle load in children 7 years old. Such studies significantly complement the assessment of the functional capabilities of a growing child's body in the period of adaptation to school, to conditions of forced hypokinesia. The observed increase in vascular tone under conditions of static muscle tension is an unfavorable prognostic factor, indicating the start of the mechanism of formation of arterial hypertension already in childhood (Shaikhelislamova et al., 2018; Shaikhelislamova et al., 2016). Reinforcing this is a shift in the excretion of NA and DA in the direction of their sharp increase, as well as strengthening the stiffness of the correlation between the parameters of vascular tone and hormonal regulators. However, at the end of the school year, the degree of CA involvement in the regulatory process of hemodynamics decreases, their reserves are depleted, and the relationship between the indicators of CA excretion and CVS is broken. Strengthening of vascular tone and maintaining stable blood pressure in children during this period is probably ensured by other neurohumoral regulatory mechanisms, which will be the subject of our further studies.

#### **IV. SUMMARY**

1. The reaction of hemodynamics to a local static load in boys of 7 years old is accompanied by an increase in the vascular component in ensuring blood pressure is characterized by signs of early fatigue in the CVS and low endurance of the child's body to isometric efforts.
2. Static load causes a shift in CA excretion: at the beginning of the school year, a significant increase in NA is observed with a decrease in DOPA; in the end - the negative dynamics of excretion of A. NA and D.A against the background of the compensatory increase in DOPA.

#### **V. CONCLUSION**

The study revealed the relationship between hemodynamic parameters and the level of catecholamine excretion in the post-isometric period in children 7 years old. The effect of HA on the state of peripheral vascular tone was proved, unidirectional changes in the level of excretion of HA and the values of DBP, OPSS after static muscular effort were established.

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