Research Article

Nervous and hormonal mechanisms of regulation of local muscle activity in 7–9-year-old children

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ABSTRACT

Aim: The reaction of urgent adaptation of the sympathetic-adrenal system (SAS) and the adrenal cortex (AC) to the local static load in 7–9-year-old children was studied, taking into account their gender, age, and initial vegetative tone. **Methods:** A shift in the excretion of catecholamines (CAs) and their precursors, metabolites of glucocorticoids and androgens, in response to the impact of a dosed load, was evaluated. It was found that the dynamics of the studied indicators in 9-year-old girls, in a state of sympathicotonia and normotonia, is multidirectional. **Results:** The observed decrease in excretion of CAs and dihydroxyphenylalanine or their insignificant increase is accompanied by an increase in the functional activity of AC and, to a greater extent, its androgenic function. **Conclusion:** All these evidenced about the features of neuroendocrine interrelations in the mechanism of adaptive reactions of 9-year-old girls, greater stability of the pituitary-adrenal system, providing metabolic processes in the growing organism. Unlike with 7-year-old boys, normotonics and vagotonics, and 8-year-old sympathotonics, whose local static load has a simultaneous decrease in the spare capacities of SAS and AC. This indicates the manifestation of fatigue and asthenization of the schoolchildren in the process of learning activity.

KEY WORDS: 7–9-year-old boys and girls, Adrenal cortex, Initial vegetative tone, Local static load, Sympathicoadrenal system

INTRODUCTION

The specificity of static loads, connected with maintaining a long contraction of a small group of muscles and peripheral vasoconstriction, is the continuous stimulation of central adrenoreceptors and pronounced activation of sympathicoadrenal system (SAS)[1,2] and that allows to estimate the state of the central mechanisms of its vegetative maintenance. The presence of a close functional relationship between the sympathicoadrenal and pituitary-adrenal systems, at the level of start-up reactions in the central nervous system, at the stages of biosynthesis and metabolism of catecholamines (CAs) and corticosteroids, gives reason to suggest that isometric exercises will cause changes in the functional activity of AC. Parallel analysis of excretion of CA, metabolites of glucocorticoids and androgens in children with different tones of the autonomic nervous system will allow to expand the concept of the neuroendocrine mechanism of regulation of local muscular activity that prevails in the daily life of the schoolchildren and can be considered as the external factor, increasing the risk of vegetative disorders and cardiovascular pathology in children,[3] especially in the period of adaptation to learning activity. In connection with the foregoing, the purpose of the study is to identify the functional state of the SAS and the adrenal cortex (AC) in the post-isometric period in children, taking into account their age-gender characteristics and vegetative tone.

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METHODS

The study involved 7–9-year-old boys and girls, who studied in the secondary school №. 1, in Kazan, belonging to the I and II groups of health. In total, 50 girls and 45 boys were selected. They were monitored continuously for 6 years. The state of SAS was determined by the content of adrenaline (A) and norepinephrine (NE) in daily urine, on the basis of the fluorometric method.[4]

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The state of AC was estimated by the content of urinary 17-oxycorticosteroids (17-OCS), which are the main metabolites of cortisol, cortisone, and their derivatives, and also by the content of 17-ketosteroids (17-KS),[5] 2/3 of which are synthesized from AC androgens, and 1/3 - from androgen gonads.[6] For the quantitative measurement of 17-KS, the colorimetric method of Samosudova and Zh.Zh. Bass was used, based on the reaction of Zimmerman in the modification of Krekhova.[7] The measurement of 17-OCS was carried out by the method of Silber and Porter, on the basis of the reaction with phenylhydrazine, after enzymatic hydrolysis.[7] The collection of urine was carried out before the functional test and 1 hour after it, during the recovery period.

The test with a local static load was carried out in the sitting position, by compressing the hand dynamometer with the left hand of the human subject, with a force equal to 50% of the maximum voluntary effort for 1 min. An average value of three attempts was taken as the indicator of maximum effort [Figure 1].

The study of the peculiarities of the cardiac rhythm vegetative regulation was carried out by the method of variational pulsometry, using the automated cardiopulmonary complex "REACARD." The cardiac rhythm was recorded for 3 min in the prone position. The heart rate, the mode (Mo), mode amplitude (AMo), and variation range (Δx) were analyzed. The initial vegetative tonus (IVT) was assessed on the basis of tension index (TI) values (TI = AMo/2Mo × Δx): The children with TI more than 95.0 relative units belonged to the sympathotonics, normotonics - were the children with TI from 46.0 to 68.0 relative units, and vagotonics - were the children with TI <46.0 relative units [Figure 2].[8]

Statistical processing of the obtained data was carried out by the standard methods of variation statistics, using the Microsoft Excel Windows 2007 software package. To assess the reliability of the differences, *t*-test, based on Student's *t*-criterion, was used.

RESULTS

The functional test in the form of a local static load causes changes in the state of SAS and AC, which is characterized by close conjugation and has specific features in age-gender groups and IVT groups. On the one hand, this confirms the existence of an interrelation between both systems of humoral-hormonal regulation,[9] and on the other hand, it is consistent with the notion of static load as a stressful factor in learning activity, especially during the period of children's adaptation to school.[3] Thus, in 7-year-old boys, with predominance of sympathicotonic influences on cardiac activity, the SAS reaction is accompanied by an increase in excretion of A,

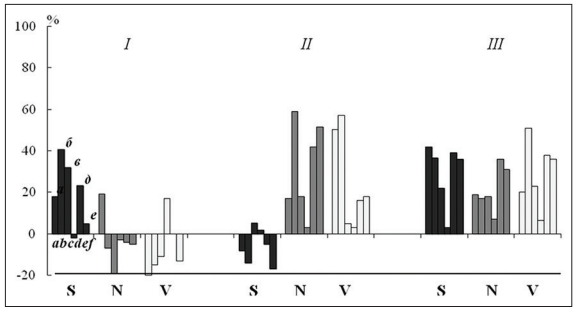

Figure 1: The change in excretion of adrenaline (a), norepinephrine (b), dopamine (c), dihydroxyphenylalanine (d), 17-ketosteroids (e), and 17-oxycorticosteroids (f) in response to the local static load of 7 (I) 8 (II) 9 (III)-year-old boys, with different initial vegetative tones in the cardiovascular system (S - sympathotonics, N - normotensive, and V - vagotonics) (in %)

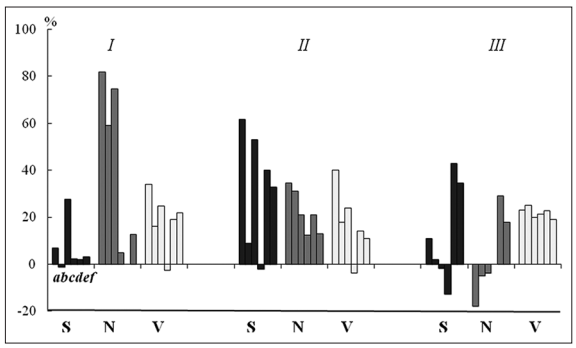

Figure 2: The change in excretion of adrenaline (a), norepinephrine (b), dopamine (c), dihydroxyphenylalanine (d), 17-ketosteroids (e), and 17-oxycorticosteroids (f) in response to the local static load of 7 (I) 8 (II) 9 (III)-year-old girls, with different initial vegetative tones in the cardiovascular system (S - sympathotonics, N - normotensive, and V - vagotonics) (in %)

NE, and dopamine (DA) by 18.34%, 39.31%, and 31.25%, respectively; herewith, the excretion of dihydroxyphenylalanine (DOPA) is lower by 1.37% that characterizes it as uneconomical accompanied by a decrease in the content of its predecessors. This is combined with positive, but less significant shifts in the excretion of 17-OCS and 17-KS, equal to 5.28% and 21.61%. The boys, in the state of normotonia and vagotonia, are of particular interest. Despite the significantly lower background level of NE excretion, its values after the load have a negative dynamics, decreasing in comparison with the rest by 8.24% and 15.84% in both IVT groups. There is a decrease in the excretion of the precursors; the compensatory increase in DOPA does not ensure corresponding increase in the CA. All these are combined with a decrease in the level of excretion of 17-OCS by 6.21% and by 14.25% in normotonics and vagotonics, respectively. At the same time, the excretion of 17-KS either decreases (5.60%) or remains unchanged. This generally indicates the low functionality of SAS and AC, which is detected after static load and can be connected with the manifestation

of fatigue and asthenization of the children organism in the period of adaptation to learning activity.[7]

Another picture is observed among 8-year-old schoolchildren. Higher level of adaptive SAS reactions, characterized by a simultaneous increase in excretion of CA and DOPA, is detected in boys in the normo- and vagotonic groups. There is the simultaneous increase in the level of excretion of NE (by 56.42% and 54.29%), DA, and DOPA (by 18.36% and 4.41%, 5.64% and 3.97%, respectively), indicating the presence of spare capacity and the economization of SAS functions. This process is accompanied by an increase in the reactivity of the androgenic and glucocorticoid functions of AC - the excretion of KS increases by 41.50% and by 14.02%, and the excretion of 17-OCS by 52.02% and by 17.00% in both IVT groups. At the same time, in sympathetic boys, the adaptive capacities of the systems under study are lower: The test isometric exercises revealed a tendency to decrease in excretion of A (by 10.05%) and NE (by 13.44%), a slight increase in DA, the absence of a positive shift in DOPA excretion, as well as the negative dynamics of the indicators of 17-OCS and 17-KS, whose values after the load are reduced by 15.61% and 6.96%, respectively.

In 9-year-old boys, the local static load reveals an increase in the activity of androgenic and glucocorticoid functions of AC in all groups of IVT, indicating probably an increase in their functional activity during maturation. The content of 17-OCS increases in the range from 22.59% to 33.57%. The excretion of 17-KS increases by 31.16%–41.00%, compared to the state of relative dormancy. At the same time, there is an increase in the excretion of CA that, in general, may indicate an increase in the adaptive reserve of the studied systems in schoolchildren of given age. Meanwhile, the most significant shifts are observed in boys in the state of vagotonia - their excretion of NE increases by 50.00% and excretion of DA - by 22.51%. The positive shift in the excretion of 17-KS and 17-OCS is also more pronounced and reaches the maximum values for a given age-gender group. This is manifested against the background of moderate activity of SAS and AC in rest. Therefore, the vagotonic type of IVT in 8–9-year-old schoolchildren, as opposed to the 7 years old, is regarded by us as the most balanced type of autonomic homeostasis regulation. In case of the latter, the increased vagal activity at rest is probably associated with compensation of initial sympathicotonia, that is, the complementary effect of adrenergic and cholinergic systems, typical for healthy children,[10] providing an adequate humoral reaction of the organism in response to the testing functional test.

In girls, compared with boys, the reactions of urgent adaptation of SAS and AC for local static load are more optimal, they are adequate to initial values of excretion of studied hormones and hormonal metabolites. For example, in 7-year-old schoolgirls, in the state of sympathicotonia against the background of increased SAS activity in rest (its mediator link), there is a tendency to decrease the level of NE excretion after the load (by 2.07%). At the same time, the excretion of DA increases, which is probably caused by compensatory acceleration of the process of DOPA decarboxylation in conditions of NE decrease, and is explained as a matter of "initial level" law, on the regulation of homeostasis.[9] The girls in the state of eutonia, after the local static load, have the greatest increase in the excretion of CA, in comparison with other studied groups - the excretion of A increases by 79.34%, NE - by 60.46%, DA - by 74.95%, and DOPA - by 4.09%, which may indicate sufficient functional and spare capacities. This process is accompanied by a positive, but less significant, shift in the excretion of 17-OCS, which increases by 12.68%. However, the greatest activity of glucocorticoid function is observed after the load in girls with vagotonic type of IVT (21.93%). They have the lowest level of excretion of 17-OCS at rest (200.60 ± 10.30 nmol/h), contrary to the group of girls - sympatotonics, where the shift is less pronounced (1.67%), and the content of 17-OCS is higher at rest (293.00 ± 12.60 nmol/h).

In 8-year-old girls, regardless of the IVT group, the local static load is accompanied by positive shifts in the excretion rates of CA, metabolites of androgens and glucocorticoids. At the same time, there is a more significant reserve of 17-KS compared to 17-OCS, which may be due to the increasing role of androgens of the AC, in the process of physical and sexual development of girls. There is an age-specific feature of the SAS response to the functional test, namely the predominance of hormonal activity over the mediator link connected with a delayed maturation of the latter.[6] There is significant increase in the excretion of A (from 39.16% to 61.15%) in various groups of IVT, while the increase in NE does not exceed 38.40%.

9-year-old schoolgirls in the state of sympatho- and normotonia have a decrease in the spare capacities of SAS, probably connected with the functional stress of the girls' organism, during the period of prepubertal neuroendocrine changes.[11] Sympathotonics have a slight increase in excretion of A and NE (by 9.36% and 1.81%) with a decrease in DA and DOPA, and normotonics have a decrease in excretion of A, a tendency to decrease in NE and DA with stabilization of the DOPA level. However, in spite of this, the functional activity of AC in these schoolgirls after the load is increased. Probably, the temporary regulatory inhibition of its glucocorticoid function at rest, observed in 8–9-year-old sympathotonic, is protective and leads to an increase in its spare and adaptive capacity after

the load, and due to this, the increase in 17-OCS is the largest (30.83% and 31.86%), in comparison with normo- and vagotonics. The multidirectional dynamics of the SAS and AC parameters indicates the features of the neuroendocrine mechanism of the adaptive reactions in 9-year-old girls, namely the greater stability of the pituitary-adrenal system, and the increase in the activity of the androgenic function of AC, which ensures metabolic processes, during the prepubertal period.

SUMMARY

1. Local static load causes shifts in the functional state of SAS and AC, the nature of which depends on the age and gender of children, the background level of excretion of hormones and hormonal metabolites, as well as the initial vegetative tone (IVT) in the cardiovascular system:

A. 7-year-old boys have an increase in NE excretion and a decrease in DOPA, in combination with positive changes in the content of 17-KS and 17-OCS, in contrast to normo- and vagotonics boys. The latter has lower preload values and simultaneous decrease in excretion of CA and their precursors, metabolites of glucocorticoids and androgens. With age, the adaptive capacities of SAS and AC increase.

B. In girls, compared with boys, the reactions of urgent adaptation of SAS and AC are more perfect, they are adequate to the background values of excretion of CA, metabolites of androgens and glucocorticoids, except for 9-year-old schoolgirls, in which the spare capacities of SAS are reduced in the state of sympathicotonia and normotonia.

CONCLUSION

The adaptation of younger schoolchildren to local static load is accompanied by interdependent reactions of the SAS and the AC, the direction of which is determined by the IVT, age, and gender of children. In general, the deformity of basic mechanisms of urgent adaptation to local muscular activity is noted, but there are some instability and imperfection. Reducing the spare capacity of SAS and AC in 7–8-year-old boys may indicate the manifestation of fatigue and asthenization of their body in the process of learning activities.

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