

Features of the Sympathoadrenal System of Primary School Age Children

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Abstract

Background/Objectives: Investigations of sympathetic-adrenal system activity of primary school children during the learning activities are rare. The study is aimed at identifying the characteristics of SAS functional state in primary schoolers.

Methods/Statistical Analysis: The study involved boys and girls of 6-8 years old enrolled in secondary school. Functional state of the sympathetic-adrenal system was evaluated by the level of adrenaline and noradrenaline excretion by fluorometric method in batch urine. The obtained data were processed by standard methods of variation statistics. To assess the statistical significance of differences the Student's t-test values were calculated. **Findings:** Analysis of the results showed that in 6-8-year-old children adaptive situation is exacerbated by the end of the school year, with the exception of the 2nd grade boys, which is associated with the ontogenetic features of body's growth and development, as adrenal segment is formed in boys earlier than in girls. Our research has shown that the educational program for six-year children is the most optimal for girls, while boys' fatigue syndrome is more pronounced, especially towards the end of the school year. It is also noted that with age, urinary catecholamine excretion increases, but this forward movement is of uneven and not infinite nature. To disclose regularities of formation of the growing organism's adaptive systems is an integral part of the scientific basis underlying the protection of the health of the younger generation. **Applications/Improvements:** The study of excretion of urinary catecholamines and their precursors in the early school years will expand the notions of neuro-humoral mechanism enabling to assess the level of adaptation possibilities of schoolchildren.

Keywords: Adaptation, Adaptation Capacity, Autonomic Regulation, Homeostasis, Sympathoadrenal System, Schoolchildren

1. Introduction

Changes in the educational strategies and technology in the modern school are usually introduced without appropriate physiological monitoring and without taking into account the functional and adaptive capacity of schoolchildren. Herewith, the adaptation capacity of children has certain peculiar features – along with the continuous growth processes, the organism must adapt to the rather heavy and intensive training load in the circumstances of the new alternative forms of learning – gymnasiums, lyceums, profiled schools and forms, in which the learning is conducted by the experimental curricula of developing learning¹. In this regard, the content and methods of educational programs should be aligned with the age-specific morphofunctional features

of the organism of schoolchildren to achieve efficiency and avoid fatigue during learning. Therefore, the problem of adaptation of schoolchildren to educational and physical loads both in the circumstances of traditional and new learning technology is a relevant issue²⁻⁴.

Primary school age is between two complex intensive periods of development and, therefore, requires special attention. At this age, there are structural and functional changes in many systems of the organism, including the neuroendocrine system, which plays a special role in the development of a child and the implementation of the genetic program of individual development⁵⁻⁸. However, in childhood the functional reserves of hormones are relatively small, the relationship between the endocrine glands is characterized by high mobility^{6,9,10}.

The Sympathoadrenal System (SAS) is part of the

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autonomic nervous system and plays a crucial role in the regulation of the adaptive reactions of a growing organism¹¹⁻¹³.

The study of urinary excretion of Catecholamines (CA) and their predecessors in the primary school age will expand the understanding of the neuro-humoral mechanism to judge about the level of the adaptation capacity of schoolchildren. SAS, its sympathetic part, is a nervous regulatory element required for launching the humoral mechanism of adaptive endocrine reactions. Catecholamines along or in conjunction with other mediators of the central nervous system implement the humoral transmission of nerve effects on the hypothalamic level and thereby activate the cortex and adrenal medulla¹⁴⁻¹⁵.

Despite the fact that CA detected in urine account for about 4-5% of their total amount metabolized in the organism, the change in their content reflects the general trend of changes in SAS. The level of Adrenaline (A) in urine allows judging primarily about the state of the hormonal element of SAS, i.e., about the activities of the adrenal medulla, and the level of Noradrenaline (NA) – about the activity of the mediator, i.e., nervous element. The status of certain elements of SAS can be judged by the ratio of Noradrenaline to Adrenaline (NA/A) in urine. This ratio grows as the activity of the mediator element increases and declines as the hormonal element's activity increases. Qualitative and quantitative changes in the CA metabolism depend on many factors: The nature, intensity, and duration of exposure, the initial state and reactivity of the central and peripheral segments of the autonomic nervous system, the presence or absence of CA reserves, homeostatic mechanisms that regulate the constancy of the internal environment, and the stability of physiological functions.

It was found that educational activity, especially in the period of adaptation, might have a negative effect on the child's organism, causing changes in the state of its nervous and endocrine systems. According to^{6,16}, SAS is the leading system in the implementation of adaptive mutations in the organism. It performs an adaptive-trophic role in the regulation of body functions.

Because of the high reactivity, to date, there are no generally accepted year-by-year age-specific standards of catecholamine excretion and it is not clear how much the ratio of the two elements of SAS changes in children. The teaching and parenting effectiveness largely depends on accounting for the adaptation capacity of schoolchildren

at different stages of ontogeny.

There are a few studies of the activity of SAS of primary school age children in the course of the educational activity^{17,18}.

In connection with the above, we defined the objective of the research – to identify the features of the functional state of the sympathoadrenal system in primary school age children during the school year.

2. Methodology

The study involved boys and girls aged 6-8 years, attending secondary school and belonging to the first and second health groups.

Based on comprehensive medical examination, we concluded that the health of the children was good. All schoolchildren surveyed had an average level of physical development and were engaged in general physical training.

The survey was conducted three times during the year - in October, February, and April, at times distant from vacations, when the influence of educational activity is expressed more than other factors affecting the child's organism.

The survey was conducted in the same days of the week and the same time of day - before noon.

Six-year-old children attending 1st grade had a five-day education week with four 35-minute lessons a day; a dynamic one-hour pause in the middle of the school day; and additional vacation in the middle of the third quarter. They had leisure activities outdoors lasting 1-1.5 hours, including games of small and medium mobility. The day sleep lasted at least 1-1.5 hours.

The functional state of SAS was evaluated by the excretion of Adrenaline (A) and Noradrenaline (NA) by the fluorometric method in batch urine⁹ using the A. D. Esikov's scheme and the 3F-3M device. Batch urine was collected before the examination.

Physical development was evaluated by the basic parameters of anthropometric measurements. The measurements of children were carried out with standard tools. Body length was measured with a wooden stadiometer accurate to 0.5 cm. Body weight was measured with medical scales. Chest circumference was measured with measuring tape in a pause.

Physical performance was determined with the PWC₁₇₀ test, which is based on the quantitative

information obtained during the muscular work. This sample is widely used in the examining athletes, as well as school-age children.

To determine PWC_{170} , we used an ERG-2 ergometer specifically designed for children from 3 to 12 years of age. For this purpose, we set two three-minute loads at a constant cadence of 60 rpm. The load was dosed individually depending on the body weight of the subject and the initial heart rate. The power of the first load in our experiment was 0.5 W/kg of the body weight, the power of the second one was 1.5 W/kg.

Statistical processing of the obtained data was performed by standard methods of variation statistics. To assess the significance of differences, we calculated the Student's t-test.

3. Results and Discussion

It would be wrong to assume based on the total reduction of CA excretion that the fatigue rises by the end of the school year, because such dynamics could also evidence the moderate activity or stability of SAS, and also act as an adaptive criterion⁶. In our opinion, this phenomenon also occurs in our studies. But the multidirectional age-specific and annual dynamics of SAS, the divergence

from seasonal fluctuations, the greater volatility of factors give grounds to state the rising fatigue in all age and sex groups, but to varying degrees.

An analysis of the functional state of SAS in children aged 6-8 years showed that the CA excretion is different in age groups.

For example, the boys aged 6 had the Adrenaline (A) excretion at 3.90 ng/min, the boys aged 8 had 4.58 ng/min; and the girls had 3.24 and 4.05 ng/m, accordingly. Significant differences were found in Noradrenaline (NA) excretion - between 6 and 7-8-year-old boys and 6-7-year-old girls. An analysis of the figures showed that there were significant sex differences in CA excretion in primary school age children (Figure 1).

It is known that the A excretion is used to define the activity of the hormonal element of SAS; the NA excretion—to define the activity of the mediator element; and the Adrenalin to Noradrenalin ratio evidences the behavior of various elements of SAS. The NA/A ratio value shows that younger schoolchildren keep high-level activity of the mediator element of SAS. This ratio is particularly high in boys aged 7 (4.14 ± 0.13). 8-year-old girls have the lowest NA/A ratio, which equals to 2.61 ± 0.29 . And its value in 7-year-old schoolgirls is 9.62 ± 0.63 .

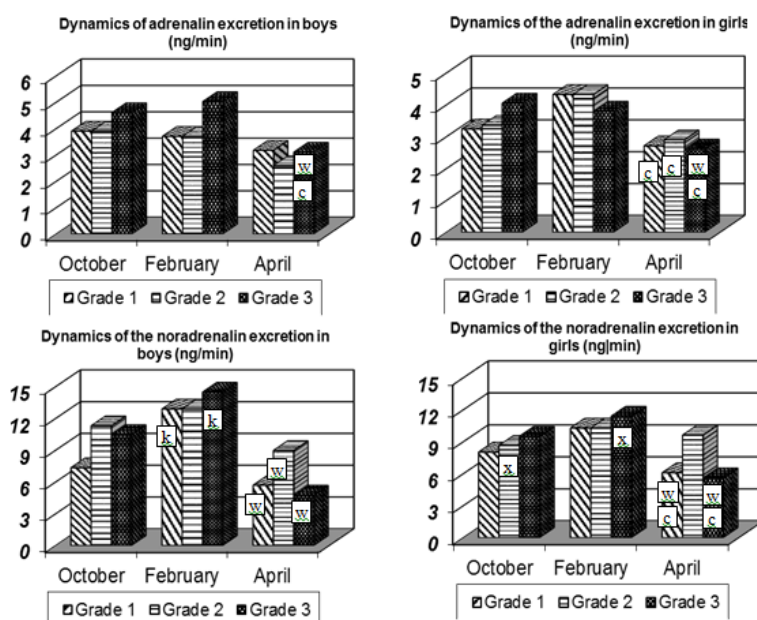


Figure 1. Changes in the catecholamine excretion in primary school age children during the school year.

The school load influence prevails over seasonal factors. In the dynamics of seasonal variations, we defined an increase in the activity in spring and a decrease in winter compared to the autumn and spring values. The obtained data show that the school year end is characterized by lower levels of CA excretion, compared with autumn and winter.

According to our data, boys aged 6-8 years have a noticeable tendency of the increasing A excretion, and undulating changes in the NA excretion. Boys aged 8 had lower NA excretion than 7-year-old boys. Girls showed a tendency to increasing the A and NA excretion level over age. Moreover, it should be noted at the age of 7 years, girls have the major increase in CA excretion and boys have the major increase in NA excretion.

The NA/A factor, which is an indirect indicator of the ratio of the activity of the mediator and hormonal elements of SAS in children aged 6-8 years, is quite high. For example, the NA/A ration of boys significantly increases by 7 years of age with a subsequent reduction by the age of 8 years. The girls' NA/A factor significantly increases already by 7 years of age.

It is clear that boys, because of the relatively lower, compared to girls, level of morpho-physiological and psychophysical organization of the organism, achieve adaptive results in the circumstances of identical work at a higher "physiological cost," which should not exceed the functional resources of the organism. Otherwise, a failure of adaptation can occur with the development of pathological conditions, as indicated by other researchers.

The ability to adapt to the new school factor of influence without homeostasis of the main systems and a failure of adaptive mechanisms can occur only at relatively high adaptive capacity of the organism, with a large functional reserve. An important role here is also played by the adequacy and efficiency of response and of the recovery of the expended resources.

By the end of the school year, the "physiological price" for adaptation increases for the primary school age children. This means that the coordination type of adaptation that is stable in autumn is replaced with the compensatory type of adaptation by spring that is unstable due to lower functional reserve and biological reliability of the sympathoadrenal and cardiovascular systems.

Overall, the obtained results provide strong evidence that with regard to the children of primary school age, the adaptive situation is exacerbated by the end of the school year, except for the 2nd grade boys. Perhaps, this is due

to the ontogenetic features of the organism's growth and development – the adrenal segment is formed earlier in boys than in girls.

According to our data, a gradual increase in the weight, thoracic organs, and body length from 6 to 8 years of age was revealed. The most notable changes in physical development were found between 6 and 7 years of age, when the body length gain equaled to 4.48%, reaching a significant value. Body length of 8-year-old boys increases in comparison with the 6-year-old ones, reaching a significant value.

The most noticeable increase of thoracic organs is observed between 7 and 8 years of age – 3.96%. The changes in the thoracic organs become smoother over age, reaching significance of the difference by the age of 8 years. The greatest increase in the mass of boys was found between 6 and 7 years of age and amounted to 13.17%.

The total body size of girls increases gradually. Significant differences in all parameters of physical development are achieved by the age of 8 years compared with schoolgirls aged 6.

The significance of differences in terms of physical development by the end of the school year was found only in boys of the third year of education and related to the increase in chest circumference. In all other cases, no significant differences were detected.

During the school year, the indicators of physical development and physical health of girls aged 6-8 change. The significance of differences in the body length increase by the middle of the school year was revealed in the first grade schoolgirls, and as for the chest circumference increase, the significant values were achieved by the second grade schoolgirls by the end of the school year.

The differences in the sex groups were insignificant and, as a rule, did not achieve a significant value for the majority of physical development indicators.

Physical performance depends on the morphological status of various systems of the body. Physical activity is a universal test, by which the functionality of the organism and its hidden reserves can be assessed. The PWC₁₇₀ test is a valuable functional test, which can be successfully used to assess the cardiorespiratory system of a person in general. The amount of physical capacity is an indicator of the functional state of the organism.

The physical capacity changes unevenly over age. According to our data, physical performance at the age of 7 years is higher than in other age groups. At the same age, an intense increase in the physical development indicators was revealed.

In all age groups of boys, a significant increase in the physical performance from the beginning to the end of the school year was noticed. Age-related changes in physical capacity per 1 kg of body weight, as well as the significance of differences are less pronounced in second and third grade schoolboys by the end of the school year.

The dynamics of physical performance is subject to seasonal fluctuations within the framework of the same age and sex groups. Studying the changes in physical performance during the school year, we noticed a gradual increase in the six-year-old schoolgirls, while schoolboys showed an abrupt increase.

By the end of the school year, the physical performance of girls increased in all age groups, but the significance of differences was demonstrated only by the second grade schoolgirls. It should be noted that the physical performance of the third grade schoolgirls undergoes minor changes during the school year. In the age groups of girls the rates of PWC_{170} increase differ to a certain extent. For example, in girls of the second year of study, PWC_{170} more intensively increased in the second half of the school year, while in other groups, this process was going smoother.

Thus, the increase in the total body size occurs evenly in children aged 6-8. With the increasing total body size by the end of the school year, the level of physical performance increases as well, except for the third grade schoolgirls. By the end of the school year, boys aged 6 in different environments and girls aged 7 significantly higher than in other age-sex groups demonstrated the interconnections between physical development indicators.

According to our data, boys of all age groups demonstrated better physical development and physical performance than girls of the respective groups.

4. Conclusions

According to our data, at the end of the school year, there was a decrease in CA excretion in all age-sex groups, except for girls aged 7 with regard to NA excretion. NA excretion significantly decreases from the beginning to the end of the school year in schoolgirls aged 6-8 years. Boys aged 8 showed a significant decrease in A and NA excretion. In the age-sex groups of third grade schoolchildren, we found a noticeable decrease in CA excretion by the end of the school year. This is especially significant in boys. The reduction in the activity of SAS by the end of the academic year is regarded as a result of the training activities' impact. The reduction in CA excretion by the

end of the school year indicates the growing fatigue.

Thus, as a result of the performed study, we found that the SAS activity in children aged 6-8 years increases over age, reflecting the increased general capacity of the organism. The NA/A factor indicates the predominant role of the mediator element in the second grade schoolchildren, whereas the first and third grade schoolchildren demonstrate the prevalent importance of the hormonal element.

The research results revealed the increased rates of physical development in children aged 6-8 years. The most notable changes in physical development were found between 6 and 7 years of age. In all age groups of girls, the body weight and length, as well as the chest circumference values are lower than those of boys in the respective groups. With regard to the body weight, significance of differences is achieved in children by the age of 8 years; and with regard to the body length and the thoracic organs – by the age of 7 years. Age-related changes in physical capacity occur unevenly in children. Significance of differences was detected by the age of 7 years in both sex groups. We know that the objective factors influencing the physical performance of the primary school age children are the level of physical development and the degree of physical fitness. Due to the fact that these groups of children showed no significant differences in physical development indicators, it can be assumed that higher values of physical performance indicators of the children are determined by their better physical fitness. By the end of the school year, an increase in the total body size, as well as in the level of physical performance was detected.

Our research has shown that this program, under which 6-year-old children are educated, is the most optimal for girls, while boys demonstrate the fatigue syndrome more evidently, especially closer to the end of the school year. It is also noted that urinal catecholamine excretion increases over age, but this forward movement is of uneven and not infinite nature.

5. References

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