

Reaction of Cardiovascular and Respiratory System of the First-Year Pupils to the Various Types of Load During the School Year

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Abstract: Study of respiratory functions and functions of cardiovascular system of 8 years old pupils of the 1st grade of secondary school, in a state of relative rest, after the graduated dynamic and static load at the beginning, in the middle and at the end of school year was conducted. It was found that the static load caused no changes in the parameters of the cardiovascular system of the first graders. Only at the end of the year, the group of girls showed changes in the parameters of the cardiovascular system. Dynamic load in all stages of research led to changes in the parameters of cardiovascular system. At the beginning of the year, boys showed adverse reaction of the parameters of external respiration. By mid year, the adaptive capacity of the cardio-respiratory system of the 8 years old children was optimal. By spring, the local static load caused adverse changes in the respiratory system of the boys. By the end of the school year, the group of first grade girls showed an adverse reaction of the parameters of external respiration to both dynamic and static load.

Key words: External respiration, a heart, physical load, cardio-respiratory system, school

INTRODUCTION

Starting learning activity at school leads to a sharp increase in psycho emotional and physical load in children (Jack *et al.*, 2003). Different types of loads cause a sharp increase in oxygen consumption of the child's nervous and muscular systems. Therefore, there is a need to compensate for increased oxygen consumption by organs and tissues. This function is ensured by a respiration process the exchange of gases between the external environment and the human body cells. Convective transportation of respiratory gases combines two processes such as pulmonary ventilation and gas transportation by circulatory system. Thus, the cardio respiratory system is a whole which provides the necessary level of oxidation reduction processes in cells.

Today, various tests of physical loads are widely used to study the adaptation mechanisms and functioning of the respiratory system (Whipp *et al.*, 2005). During tests, special attention is paid to the types and intensity of physical load (Ozyener *et al.*, 2003). It is shown that the behavior and psychological stress have a significant effect on the respiratory system (Jack *et al.*, 2003). There are researches conducted with the aim of studying the influence of physical loads on the respiration of children with respiratory disorders as well as children from ecologically unfavorable regions (Jack *et al.*, 2004; Marchal *et al.*, 2004). A simultaneous

analysis of the reaction of the respiratory, muscular and cardiovascular system during physical loads has been carried out in a number of studies (Whipp *et al.*, 2005; Jack *et al.*, 2004). However, most of the studies were carried out with the use of dynamic loads of different capacities and the emphasis was placed on the study of the parameters of cardiac activity (Kuznetsova, 1986; Sokolov *et al.*, 2000). Other researchers have mainly studied the effect of static loads common to the educational process (Batenkova *et al.*, 2004). Static efforts aimed at maintaining the working position are those of one of the adverse factors of educational activity in primary schools (Antropova, 1983). Therefore, a comparative analysis of the influence of static and dynamic loads on the respiratory function of graders is of undoubted scientific interest. The originality of the physiological changes that occur in the respiratory system under static loads and a quickly occurring fatigue make them an important object of study, especially in the process of adaptation of graders. The common patterns of development of external respiration, its reserve and adaptive capacity in the ontogeny of children and adolescents have studied comprehensively by domestic and foreign authors. Nevertheless, there is a lack of simultaneous study of convective transportation components in different types of testing of physical activity in the period of adaptation to a new type activity, namely learning at school. The dynamics of the

parameters of external respiration and cardiovascular system during the school year is of absolute interest. A working hypothesis of our research was the assumption of an unfavorable effect of static loads in different periods of the school year on the parameters of convective transportation in the first graders. Objective of our study was to investigate the effect of different types of testing physical loads on the components of convective transportation of gases during adaptation to school learning process. In accordance with the objective, the following tasks have been set: to study the respiratory functions and functions of cardiovascular system of boys and girls of the 1st grade of secondary school in a state of relative rest, after dynamic and static load at the beginning (October) in the middle (February) and at the end (May) of school year.

MATERIALS AND METHODS

The study involved 45 boys and girls of the 1st grade of the secondary school in Kazan, virtually healthy with an average level of physical development. Total three studies were conducted during a year in October, February and May. In order to eliminate the influence of daily and weekly rhythms, the subjects were invited on the same day of the week and time of day. We used an automated cardiopulmonary Pentium I-based AD-03M system. The functional state of the respiratory system was evaluated by lung volume and ventilation parameters: Lungs Vital Capacity (LVC), inspiratory and expiratory Reserve Volume (RV_{in}, l and RV_{ex}, l) Reserve Volume at Resting Ventilation (RRV, l) the Maximum Pulmonary Ventilation (MPV, l/min) as well as Pulmonary Minute Volume, Respiratory Volume, Respiratory Rate (PMV, l/min, RV, l, RR c/min) and Forced Expiratory Volume in 1 sec (FEV-1, l). External respiration indices were registered for 1 min after completing the static and dynamic loads. To evaluate the functional state of the Cardiovascular System (CVS) of the pupils under various types of load we used indicators such as heart rate, stroke volume, blood min volume, blood pressure (HR, bpm, SV, l, BMV, l/min, BP, mmHg) and also studied heart rate variability by P.M. Baevsky's method. Stroke volume was calculated from the blood pressure according to the formula: $B_{pav} * 100 / HR$. Cardiac output was calculated by formula: $HR * SV$. Cardiovascular indicators were recorded at 1, 3, 5, 7 and 9 min after completion of loading. Comparative analysis of the external respiration and cardiovascular indicators was conducted with the use of data of the 1st min of observations. Isometric physical load test was conducted in a sitting position, by compressing a dynamometer with the left hand by force

equal to 50% of the maximum force within 1 min. The average of three attempts was taken as the indicator of maximum produced force. The graduated physical load was set at a bicycle ergometer with magnetic retardation and was 1.0 W per 1 kg body weight, the pedaling duration was 5 min, frequency 60 rev/min. Lung volumes and ventilation parameters are given in BTPS system. The reliability was determined with the use of t-test standard values.

RESULTS AND DISCUSSION

The results of studies show that 8 years old girls had maximum LVC recorded in February 1.66 ± 0.17 L, exceeding by 11.7% ($p < 0.001$) and by 10.5% ($p < 0.05$) the indicators obtained in October and May, respectively. Increase in LVC was ensured by growth of RV_{ex} ($p < 0.01$). Simultaneously with LVC, the dynamic lung volumes and indicators of respiratory reserves were changing within a school year. From October to February, there was an increase in the value of FEV-1/LVC from 68.99 ± 0.371 to 75.63 ± 1.08 L ($p < 0.05$). Simultaneously, there was a decrease of activity of the ventilation function. In Autumn, PMV was 14.9 ± 0.6 L min⁻¹ and in February its value decreased by 35% ($p < 0.05$). By the end of school year, the PMV value increased up to 13.9 ± 0.63 L min⁻¹ ($p < 0.01$). At the same time, PMV changes occurred with equal participation of the frequency and volume components. At the beginning of the school year, first graders' HR values were 83.18 ± 1.16 bpm, BMV- 3.24 ± 0.31 L. From October to May, the girls showed a gradual decrease in BMV value by 25% ($p < 0.05$), due to a decrease in heart rate ($p < 0.05$) and SV ($p < 0.05$). Static load in autumn and winter caused no significant changes in indicators of cardio-respiratory system of the girls. At the end of the school year, static load caused an increase in PMV by 22% ($p < 0.05$), due to decrease of RV and increase of RR ($p < 0.01$) which indicates an uneconomical reaction of the respiratory system to a graduated static load. At the same time, BMV value increased by 43% ($p < 0.05$)

Dynamic load in October and in February led to no significant changes in the parameters of external respiration of the girls. In spring, dynamic load led to an increase in PMV values by 30% ($p < 0.05$).

At the same time, RV decreased and RR increased ($p < 0.01$) which indicates reduced respiratory efficiency. In all study periods there was an increase of BMV values (Fig. 1), SV (Fig. 2), HR (Fig. 3) and increased blood pressure after cycloergometric test.

The boys of the 1st grade had LVC values at the beginning of the school year equal to 1.470 ± 0.16 L while

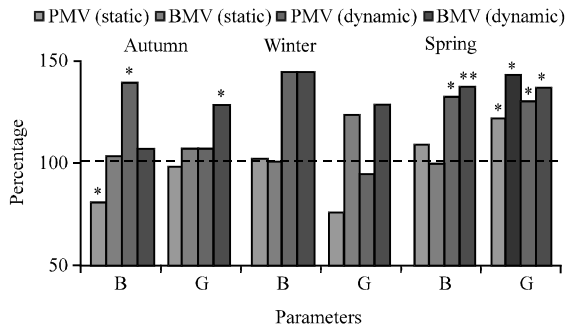


Fig. 1: The reaction of cardio-respiratory parameters of the first graders to static and dynamic load at the beginning in the middle and at the end of the school year. PMV: Pulmonary Min Volume, BMV: Blood Minute Volume, B: Boys, G: Girls. The statistical significance of differences in the indicators after the physical loads in relation to the initial index (taken as 100%); *p<0.05; **p<0.01

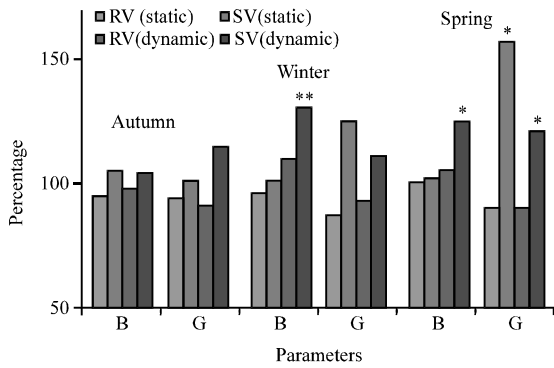


Fig. 2: The reaction of cardio-respiratory parameters of the first-graders to static and dynamic load at the beginning in the middle and at the end of the school year. RV: Respiratory Volume, SV: Stroke Volume, B: Boys, G: Girls. The statistical significance of differences in the indicators after the physical loads in relation to the initial index (taken as 100%); *p<0.05; **p<0.01, stroke volume by 50% (p<0.05)

in February and in May this index decreased by 2.8 and 3.5%, respectively. Such dynamics of LVC values is associated with a reduction in both R_{vin} and R_{vex}. Minimal respiratory rate was observed in February, equal to 16.43±0.81 c/min in October and May it was higher by 34% (p<0.001) and 29% (p<0.001), respectively. RV value in autumn was 0.62±0.1 L PMV was 10.430.74 L min⁻¹. During the school year, both RV and PMV increased exceeding the initial values obtained in May by 22.5% (p<0.05) and 51.7% (p<0.01). Dynamics of indicators

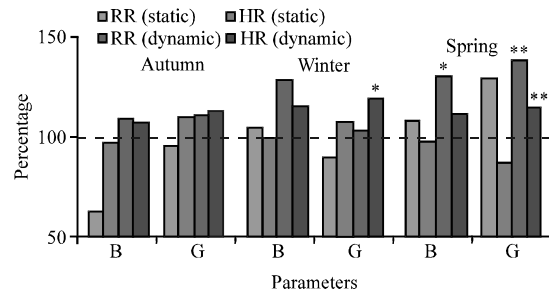


Fig. 3: The reaction of cardio-respiratory parameters of the first-graders to static and dynamic load at the beginning in the middle and at the end of the school year. RR: Respiratory Rate, HR: Eart Rate, B: Boys, G: Girls. The statistical significance of differences in the indicators after the physical loads in relation to the initial index (taken as 100%); *p<0.05; **p<0.01

suggest that in the middle of the school year the external respiratory system of 8 years old boys was in a favorable functional state; by the end of the school year there was a tension of the respiratory system of the pupils an as a consequence, an increase in the respiratory rate. In October, HR of first graders was 80.9±1.06 bpm, BMV 3.89±0.45 L. In the middle of the school year there was a decrease in BMV by 23% (p<0.05) while HR (p<0.05) and SV (p<0.05) decreased significantly. By the end of the school year, the cardiovascular parameters recovered up to October values. Static load at the beginning of the school year led to a decrease in PMV by 19.2% (p<0.01) at the expense of decrease in RR by 37.5% (p<0.001) and RV by 5%. After the dynamic load, there was an increase in PMV due to accelerated breathing. The LVC, MPV and RRV values tended to decrease. In the middle of the school year, lung ventilation parameters did not change after static load. At the same time, RRV/MPV value decreased by 4.7% (p<0.05). More favorable reaction was observed after the dynamic load PMV increased both due to the frequency and volume components as well as LVC. At the end of the school year, static load led to an increase in PMV of the boys on account of frequency component. At the same time, RRV decreased by 20.2% (p<0.05), MPV by 15.1% (p<0.05). After dynamic load a favorable reaction was observed in lung ventilation parameters and functionality of the respiratory system of the first graders. In autumn, a dynamic load caused an increase in HR up to 85.6±1.29 bpm during the 1st min of observations, SBP up to 118.3±1.01 mm Hg (p<0.01). On the 5th min increase in HR was the highest (91±1.25 bpm) (p<0.05). In February and May, a dynamic load led to

an increase in BMV ($p < 0.01$). In winter, the maximum increase in HR was observed on the 5th min after dynamic load (91.88 ± 1.48 bpm) ($p < 0.05$). In spring, the HR value increased in 1 min after dynamic load up to 85.5 ± 1.55 bpm, BMV up to 4.22 ± 0.33 L ($p < 0.01$), SV up to 49.91 ± 1.07 mL ($p < 0.05$). Increase in systolic ($p < 0.01$) and diastolic blood pressure was not significant. Static load did not lead to significant changes in cardiovascular parameters of boys throughout the school year.

SUMMARY

- Adaptation of cardio-respiratory system of the first graders to the learning load during the 1st year of study has significant differences
- At the beginning of the year, there was an increased tension of the external breathing system observed in boys as evidenced by the increase in its frequency component
- In the mid-year, the adaptive capacity of the cardio-respiratory system of the 8 years old children was optimal. In spring, the local static load caused adverse changes in the external respiratory system of the boys

CONCLUSION

The obtained results allow us to conclude that the adaptation of cardio-respiratory system of the first graders to the learning load during the 1st year of study has significant differences. At the beginning of the year, there was an increased tension of the external breathing system observed in boys as evidenced by the increase in its frequency component. In the mid-year, the adaptive capacity of the cardio-respiratory system of the 8 years old children was optimal. In spring, the local static load caused adverse changes in the external respiratory system of the boys. In our view, this reaction may be due to fatigue of the organism of children in response to the static loads increasing with the start of school year. In girls, physical fatigue by the end of the school year was manifested as an adverse reaction of the indicators of both the cardiovascular system and the system of external respiration in response to dynamic and static load that can be considered as a tension of cardio-respiratory system of girls in general.

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REFERENCES

- Antropova, M.V., 1983. Reaction of the main physiological systems of 6-12-year-old child body during adaptation to the learning load. *Hum. Physiol.*, 9: 18-24.
- Batenkova, I.V., N.P. Gorbunov and R.A. Shabunin, 2004. Status of the cardiorespiratory system of younger pupils adapted to static tension. *Sechenov Rus. Phys. J.*, 90: 350-350.
- Jack, S., H.B. Rossiter, C.J. Warburton and B.J. Whipp, 2003. Behavioral influences and physiological indices of ventilatory control in subjects with idiopathic hyperventilation. *Behav. Modification*, 27: 637-652.
- Jack, S., H.B. Rossiter, M.G. Pearson, S.A. Ward, C.J. Warburton and B.J. Whipp, 2004. Ventilatory responses to inhaled carbon dioxide, hypoxia and exercise in idiopathic hyperventilation. *Am. J. Respiratory Critical Care Med.*, 170: 118-125.
- Kuznetsova, T.D., 1986. Age features of breathing in children and adolescents. *Medicine, Moscow*, Pages: 128.
- Marchal, F., C. Schweitzer, B. Demoulin, C. Chone and R. Peslin, 2004. Filtering artefacts in measurements of forced oscillation respiratory impedance in young children. *Physiol. Measurement*, Vol. 25.
- Ozyener, F., H.B. Rossiter, S.A. Ward and B.J. Whipp, 2003. Negative accumulated oxygen deficit during heavy and very heavy intensity cycle ergometry in humans. *Eur. J. Applied Physiol.*, 90: 185-190.
- Sokolov, E.V., T.D. Kuznetsova and I.P. Samburova, 2000. Age development of the reserve and adaptive capacities of the respiratory system. *Physiology of Child Development, Moscow*, pp: 167-184.
- Whipp, B.J., S.A. Ward and H.B. Rossiter, 2005. Pulmonary O₂ uptake during physical load: conflating muscular and cardiovascular responses. *Med. Sci. Sports Exerc.*, 37: 1574-1585.