

The Effect of Controlled Static Exercise on the Respiratory System Indices in Children Throughout the School Year

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Abstract: Study of adaptive response of the 9 years old boys' respiratory system to controlled isometric exercise in the course of the school year. The dynamics of the lung ventilatory capacity indices as defined at rest as well as the degree of their change due to isometric exercise had been analyzed during the school year in 38 sophomore boys. An automated cardiopulmonary facility AD-03M based on Pentium I processor was used for analysis of the respiratory system indices. Dosed isometric load was created by compression of a hand dynamometer (50% of maximum possible effort within 1 min). Statistical processing of the study results was performed using Student's t-test. A comparative analysis of the external respiration system of the 9 years old boys during the school year showed positive age-related dynamics of the lung volumes indices and the lung ventilatory capacity at rest. Dosed isometric load results in unfavorable changes in the external respiration indices and reduction of the respiratory system reserve capacity. By the end of the second school year the 9 years old boys experience increase of reactivity and lowering of the respiratory system responses efficiency as a reaction to static exercise.

Key words: Respiratory system, isometric exercises, external respiration indices, adaptive responses, age dynamics

INTRODUCTION

Start of a child's learning activity is accompanied by significant increase of static load and decrease of dynamic one. It is therefore, necessary to match the imposed requirements with physiological capabilities of pupil. Study of the systems of a developing body which ensure the capability of the body to adapt to the variable environmental conditions is obviously of current interest.

Most of the investigations are dedicated to study of dynamic loads with various intensity in order to assess the cardiac function, nevertheless the respiration process is one of the leading processes and identifies adaptive capabilities of a child's body. The effect of dynamic exercise on the cardiorespiratory system indices was studied in the works of a range by Zayneev *et al.* (2012a, b) and Sokolov *et al.* (2000). Various physical test exercises are used for study of the children's respiratory system mechanisms of adaptation to endogenous actions (Marchal *et al.*, 2004; Ozyener *et al.*, 2003; Palange *et al.*, 2007; Puente-Maestu *et al.*, 2000; Rossiter *et al.*, 2006; Stringer *et al.*, 2005; Whipp, 2007). It is known that

functional state of the respiratory system to a large extent determines adaptive capabilities of a child's body to different forms of activity inclusive of study load (Ferguson *et al.*, 2007; Puente-Maestu *et al.*, 2000).

Therefore, examination of particularities of the junior school children respiratory system responses to various types of load in the course of adaptation to the learning activity appears to be rather important.

The research is aimed at study of adaptive responses of the 9 year old boys' respiratory system to a dosed isometric exercise throughout the school year.

In the course of this study, we have analyzed both the dynamics of external respiration parameters determined at rest and the system responsiveness evaluated by the rate of change of the lung volumes and the lung ventilatory capacity indices under the action of the isometric exercise three times per the school year (autumn, winter, spring).

The investigation involved thirty eight, 9 years old sophomore boys with mesosomia referring to the 1st and the 2nd health groups and studying at a general education school of Kazan City.

An automated cardiopulmonary facility AD-03M based on Pentium I processor was used for analysis of the respiratory system indices. The investigation was performed over the school year with due account for the effect of circadian and weekly biorhythms.

The following respiratory system indices were subject to evaluation: Vital Lung Capacity (VLC), Respiratory Minute Volume (RMV), Respiratory Capacity (RC), Respiratory Rate (RR), Inspiratory Reserve Volume (IRV) and Expiratory Reserve Volume (ERV), Reserve volume at quiet Lung Ventilation (RLV), Maximal Lung Ventilation (MLV). In order to assess, the respiratory efficiency an inspiratory and expiratory time to total breath cycle time ratio was examined. The lung volumes and the lung ventilatory capacity indices are given in BTPS (Body Temperature and Pressure Saturated body temperature, ambient atmospheric pressure at time of observation, total saturation with aqueous vapors) system.

Dosed isometric load from compression of a hand dynamometer was used as a functional muscle test (Anikina *et al.*, 2011). The isometric physical exercise was performed by a test person by means of the left-hand compression of a dynamometer with the effort equal of 50% from the maximum possible effort within 1 min. Average value of three attempts was regarded as an index of the maximum possible effort. The values received at rest were used as controls for the external respiration indices. Change of the external respiration parameters due to the testing effort was registered during the first minute after the static exercise stop. A correlation analysis of interrelations between all respiratory system parameters being examined was performed. Statistical processing of the investigation results was carried out in accordance with the established methods of analysis of variance; standard values of Student's t-test were used to evaluate statistical significance.

THE MAIN PART

The investigation of the respiratory system of 9 years old boys at rest conducted at the beginning of the school year showed the following results: RMV made $11.54 \pm 0.36 \text{ L min}^{-1}$, RC: $0.59 \pm 0.09 \text{ L}$, RR: $19.49 \pm 0.3 \text{ cycles/min}$, VLC: $1.85 \pm 0.17 \text{ L}$. The indices evidencing the reserve lungs capacity (ERV, IRV, RLV, MLV) made 0.35 ± 0.07 , 1.00 ± 0.08 , 63.87 ± 1.18 , $73.23 \pm 1.04 \text{ L}$, correspondingly.

Examination of the respiratory system adaptive responses to isometric load in the sophomore boys at the beginning of the school year revealed that the value of RMV increased up to $13.26 \pm 0.29 \text{ L min}^{-1}$ (by 14.81%,

$p < 0.05$) of the respiratory rate up to $21.04 \pm 0.39 \text{ cycles/min}$ (by 8.05%, $p < 0.05$) while RC remained almost unchanged (Fig. 1). Therefore, during the first investigation stage isometric load results in the growth of RMV in the boys only due to the Respiration Rate (RR) component of lung ventilation.

To the contrary, the values of VLC and of the indices reflecting reserve lung volumes in response to the functional test tended to reduce (Fig. 1). VLC after load went down as much as to $1.71 \pm 0.15 \text{ L}$, IRV up to $0.83 \pm 0.19 \text{ L}$, ERV up to $0.33 \pm 0.12 \text{ L}$ and the values of RLV and MLV demonstrated positive decrease. For example the value of RLV after the exercise constituted $55.8 \pm 1.05 \text{ L}$, MLV: $68.44 \pm 1.08 \text{ L}$ (reduced by 12.6% and 7.55%) correspondingly ($p < 0.05$). The correlation analysis of interrelations between the boy's respiratory systems indices at rest allowed to establish direct correlation dependence between RR and RMV ($r = 0.58$; $p < 0.05$) as well as between RMV and RC ($r = 0.49$; $p < 0.05$).

There was discovered strengthening of interrelations between RR and RMV ($r = 0.71$; $p < 0.05$) after the exercise. At the same time a change of a vector of interrelations between RMV and RC ($r = -0.34$; $p < 0.05$) which evidenced mismatching of the mentioned breathing components functions was reported.

In general, the results of the adaptive responses investigation received at the school year beginning evidence insufficient readiness of the respiratory system of the sophomore schoolboys to experience isometric load.

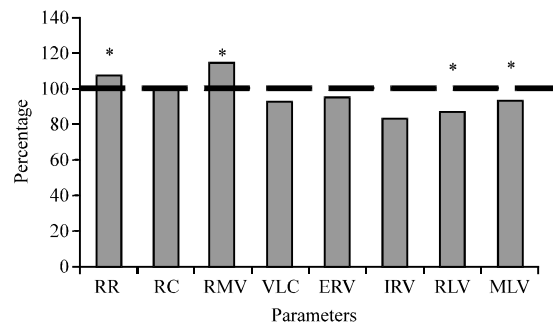


Fig. 1: Response of the external respiration indices in 9 years old boys to static load at the school year start. RR: Respiratory Rate, RC: Respiratory Capacity, RMV: Respiratory Minute Volume, VLC: Vital Lung Capacity, ERV: Expiratory Reserve Volume; IRV: Inspiratory Reserve Volume, RLV: Reserve volume at quiet Lung Ventilation, MLV: Maximal Breathing Capacity. Statistical significance of variations of the indices after the exercise as compared to the initial index value (assumed to be 100%); * $p < 0.05$

In the middle of the school year the basic respiratory system indices (at rest) in the sophomore schoolboys had no significant differences as compared to the results of the previous investigation period despite of strong upward trend.

The isometric exercise resulted in minor breathing rate increase and RMV growth while the value of RC remained unchanged (Fig. 2). In the meantime after the exercise termination there was observed reduction of VLC (from 1.85±0.18 to 1.67±0.15 L), RLV (from 66.35±1.04 to 52.90±1.06 L) and MLV (from 76.18±1.07 to 65.57±1.11 L) and as a consequence decrease of the ratio of RLV/MLV ($p < 0.05$) (Fig. 3).

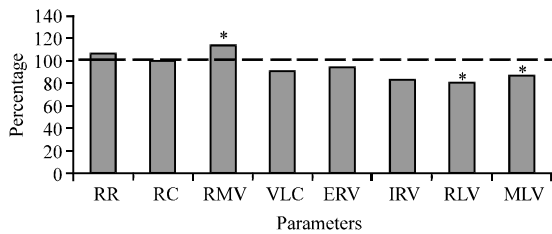


Fig. 2: Response of the external respiration indices in 9 years old boys to static load in the middle of the school year. RR: Respiratory Rate; RC: Respiratory Capacity; RMV: Respiratory Minute Volume; VLC: Vital Lung Capacity; ERV: Expiratory Reserve Volume; IRV: Inspiratory Reserve Volume; RLV: Reserve volume at quiet Lung Ventilation; MLV: Maximal Breathing Capacity. Statistical significance of variations of the indices after the exercise as compared to the initial index value (assumed to be 100%); * $p < 0.05$

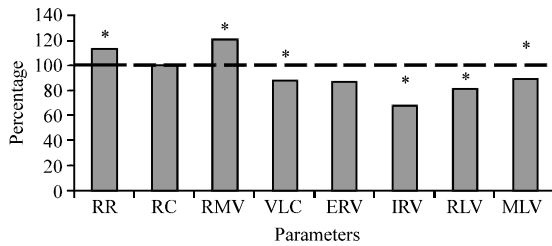


Fig. 3: Response of the external respiration indices in 9 year old boys to static load at the school year end. RR: Respiratory Rate; RC: Respiratory Capacity; RMV: Respiratory Minute Volume; VLC: Vital Lung Capacity; ERV: Expiratory Reserve Volume; IRV: Inspiratory Reserve Volume; RLV: Reserve volume at quiet Lung Ventilation; MLV: Maximal Breathing Capacity. Statistical significance of variations of the indices after the exercise as compared to the initial index value (assumed to be 100%); * $p < 0.05$

The received results evidence unfavorable nature of adaptive responses of biomechanical breath characteristics in reply to isometric load and reflect low reserve capacities of the respiratory system. The value of other examined external respiration indices had no significant differences as compared to the baseline state after isometric load.

The correlation analysis of interrelations of the respiratory system indices at rest carried out in the middle of the school year allowed to detect existence of a direct correlation dependence between RR and RMV ($r = 0.53$; $p < 0.05$) as well as between RMV and RC ($r = 0.43$; $p < 0.05$). After the isometric exercise the indices RR, RMV, RC had inverse interrelation. There was revealed existence of negative relationship between RR and RMV ($r = -0.38$; $p < 0.05$) as well as between RMV and RC ($r = -0.36$; $p < 0.05$) which evidences intense functioning of the boys' respiratory system.

The examinations performed at the end of sophomore school year showed that the values of RMV, RR, RLV, MLV at rest increased significantly as compared to the previous analyzed periods. RMV made $15.07 \pm 0.41 \text{ L min}^{-1}$, RR: $23.76 \pm 0.38 \text{ cycles/min}$ ($p < 0.05$), RLV: $69.70 \pm 1.27 \text{ L}$, MLV: $79.59 \pm 1.20 \text{ L}$ while the dynamics of RC, VLC, ERV, IRV demonstrated only a tendency to positive age-specific growth of the indices.

After the isometric exercise at the end of the school year there was observed significant increase of RMV (up to $18.94 \pm 0.58 \text{ L}$, $p < 0.05$) conditioned by the growth of RR (up to $27.49 \pm 0.49 \text{ cycles/min}$, $p < 0.05$). Incremental value of RMV made 26.9% of RR: 14.8% (Fig. 3). The value of RC after the exercise remained unchanged. In the meantime, there was observed an accentuated decrease of the most of the external respiration indices: RLV (up to 57.00 ± 1.07 , $p < 0.05$), MLV (up to 71.33 ± 1.01 , $p < 0.05$), VLC (from 1.89 ± 0.03 to $1.65 \pm 0.03 \text{ L}$, $p < 0.05$), IRV (from 1.02 ± 0.11 to $0.60 \pm 0.10 \text{ L}$, $p < 0.05$). The value of ERV showed a tendency to decrease (from 0.44 ± 0.18 to $0.38 \pm 0.14 \text{ L}$) and RLV/MLV ratio was positively going down ($p < 0.05$).

Attention is drawn to the fact that at the end of the school year there is a tendency to increase of the ratio of the expiratory time and decrease of the ratio of inspiratory time to the total breath cycle time (from 0.47 ± 0.08 to $0.53 \pm 0.08 \text{ sec}$ and from 0.53 ± 0.07 to $0.47 \pm 0.06 \text{ sec}$ correspondingly, $p < 0.05$) which is indicative of decrease of the external respiration efficiency during this investigation period.

The correlation analysis of interrelations between the respiratory system indices carried out at the end of the school year demonstrated existence of a direct correlation dependence between RR and RMV ($r = 0.55$; $p < 0.05$) as well as between RMV and RC ($r = 0.48$; $p < 0.05$).

After the isometric exercise the degree of linking of RR and RMV indices was rather high ($r = 0.89$; $p < 0.05$). In the meantime there was established a negative interrelation between RMV and RC ($r = -0.36$; $p < 0.05$) which evidences intense functioning of the boys' respiratory system at the end of the school year.

The comparative analysis of the age-related dynamics of the lung volumes and the lung ventilatory capacity indices in the 9 years old boys throughout, the school year showed that all parameters of the respiratory system as determined at rest have clearly defined tendency to increase in the period from the beginning to the end of the school year. The most significant growth was observed in relation to such indices as RMV (14.5%, $p \leq 0.05$) and RR (21.9%, $p \leq 0.05$). The increment value of RC was less expressive and made as much as 6.7%.

The correlation analysis of interrelations between the respiratory system indices at rest allowed to establish existence of a direct correlation dependence between RR, RC and RMV ($p < 0.05$) throughout the duration of the school year.

It is particularly remarkable that in the course of the school year the growth of the value of RMV at rest is taking place with involvement both of the rate and volume ventilation components which is indicative of rather favorable age-related dynamics of the respiratory system dynamics in the 9 years old boys.

Age-related growth of the indices reflecting the respiratory system reserve capabilities is also regarded as a positive aspect. Intense growth of RLV (9.1%, $p \leq 0.05$) and MLV (8.7%, $p \leq 0.05$) as well as growth tendency of IRV and ERV were observed by the end of the school year.

The comparative analysis of adaptive responses of the respiratory system of the sophomore boys to the dosed isometric exercise demonstrated that during all investigation periods there was observed decrease of VLC, IRV, ERV, MLV, RLV indices as compared to their level at rest, occurrence of negative correlation interrelationships between RMV-RC-RR which was indicative of unfavorable response of the system exposed to the stated test load.

It is remarkable that growth of RMV in response to isometric load is mainly ensured due to the rate (RR) component at a time when RC shows minimum changes.

By the end of the sophomore year the boys demonstrated gain of responsiveness and loss of efficiency of the respiratory system responses to static load which reflects intensive functioning of the mentioned system by the end of the school year.

RESULTS

The 9 years old boys during the school year demonstrate positive age-related dynamics of the lung volumes and the lung ventilatory capacity at rest.

The dosed isometric exercise performed by the 9 years old boys results in unfavorable changes of external respiration indices as well as decrease of the respiratory system reserve capabilities.

By the end of the sophomore year the boys experienced gain of responsiveness and loss of efficiency of the respiratory system responses as reaction to isometric load.

The respiratory system of the sophomore school boys is insufficiently adapted to the isometric exercise which is demonstrated by intensive external respiration system functioning at the end of the school year.

It is necessary to take into account the established regularity of the respiratory system responses to the test load at time of planning static and dynamic exercises, labor and rest routine arrangement as well as assessment of the level of adaptation of the primary school-aged children to study loads in the course of the school year.

CONCLUSION

The respiratory system of the sophomore boys is insufficiently adapted to isometric exercises which is demonstrated by intense system functioning at the end of the school year.

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