Section 1. Biology

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IMPROVING EXTERNAL RESPIRATORY FUNCTION IN PRIMARY SCHOOL CHILDREN IN THE CONDITIONS OF THE REPUBLIC OF KARAKALPAKSTAN

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Abstract

The issues of improving external respiratory function in young schoolchildren in the conditions of the Republic of Karakalpakstan are considered. It is shown that there is a high interdependence between the physical development of children and the development of lung ventilation function, as well as the mechanisms of its regulation. The identified relationships in the levels of lung ventilation function development and physical development are consistent and are determined by the heterochrony and unevenness of maturation of each of the studied systems.

Keywords: *external respiration, regulatory mechanisms, Karakalpakstan, reserve capacities, younger generation*

Research in the field of physiology and respiratory biochemistry at the end of the 19th and 20th centuries is known for the development of the diffusion model of gas exchange. The creation of the theory of functional systems and the study of adaptation mechanisms have contributed to the development of various correction methods for respiratory and gas exchange disorders (Minyaev V. I., Minyaeva A. V., Morozov G. I., Petushkov M. N. et al., 2012; Solopov I. N., 2004).

The priority task of society and the state is to preserve and strengthen the health of the younger generation (Kotova A. V., Losevoy T. N., 2011). Children's health reflects the integrated system of material and spiritual relationships existing in society and largely depends on the quality of the natural environment, upbringing conditions, family relationships, the state of the healthcare system, and other factors (Agajanyan N. A., Makarova I. I., 2001; Anokhin P. K., 1978).

The respiratory system is most strongly affected by negative environmental factors, which underlie the high percentage of diseases of the upper respiratory tract, bronchi, and lungs in children, leading to a decrease in respiratory reserve capacities. It is precisely due to this group of illnesses that children have the highest number of school absences. At the same time, only the school, being the only organized form of social upbringing in the country, covering the entire child population of the country for a long period (from 7 to 17 years), can become the basis for implementing the most modern and effective prevention and health promotion programs (Baevsky P.M., Berseneva A.P., 1997; Berseneva A.P., 2006).

It is known that the respiratory system is one of the leading and largely determining factors of aerobic and anaerobic performance of the body (Dubilei V.V., Dubiley P.V., Kuchinn S.N., 1991; Kabirova E.I., 1989). Breathing is one of the most important forms of constant interaction with the external environment. Attempts to study it and find a connection between breathing, mental state, and health were made in ancient times. Subsequently, at various stages of the development of philosophy and natural science, these attempts received further development (Berseneva A.P., 2006).

Anaerobic capabilities are determined by the ability to use energy in oxygen-deficient conditions, depending on the power of the corresponding enzymatic systems, reserves of energy substances in tissues, the ability to compensate for shifts in the body's internal environment, and the level of tissue adaptation to hypoxic conditions (Breslav I.S., Segizbaeva M.O., Isaev G.G., 2000; Kabirova E.I., 1989).

Aerobic and anaerobic capacities fully characterize the functional "ceiling" of human energy exchange – overall energy capabilities. It should be noted that all bioenergetic reactions that support muscle activity are closely interconnected and typically trigger one another (Kuchkin S.N., 1988; Matyskin A.V., 2006).

There is a high interdependence between the physical development of children and the development of lung function, as well as the mechanisms regulating it. Authors believe that biological age (Bezrukikh, M.M., Farber D.A., 2010), somatotype characteristics, child's adaptive response type (Rubanovich V.B., Girienko L.A., Aizman R.I., 2003), nature of motor activity, environmental and genetic factors significantly influence the pace of physical development and the level of respiratory system functioning (Berseneva A.P., 2006), (Breslav I.S., Segizbaeva M.O., Isaev G.G., 2000; Kabirova E.I., 1989). Between 8 and 9 years of age, against the backdrop of intensified bronchial tree growth, relative alveolar lung ventilation significantly decreases along with the relative oxygen content in the blood. After 10 years, following the relative stabilization of functional indicators, age-related transformations intensify – lung volumes and elasticity increase, relative lung ventilation and oxygen absorption by the lungs decrease even more, and functional indicators start to differ between boys and girls (Bezrukikh, M.M., Farber D.A., 2010). The abundance of interstitial tissue with numerous bronchioles in children's lungs is also a characteristic feature of the respiratory organs, associated with frequent inflammatory processes in the lungs. This necessitates constant care for air cleanliness in educational institutions, proper ventilation, humid cleaning of premises, and adherence to sanitary and hygienic rules (SanPiN No. 0341–16).

The study of the respiratory function of primary school children was carried out using the portable spirometer "SPIROVIT SP-1 – Schiller" (with a pneumotachometer SP-20) manufactured in Switzerland according to standard methods. The following types of spirometric tests were performed with each child: quiet breathing, vital capacity, forced vital capacity, maximum lung ventilation, and functional tests (Bezrukikh, M.M., Farber D.A., 2010; Gamza N.A., Solyanko G.R., Zhukova T.V., 2010).

It is known that the main indicator of spirometry is the vital capacity of the lungs (FVC), which represents the maximum volume of air that can be inhaled (inspiratory FVC) or exhaled (expiratory FVC). The main requirement for measuring FVC is the completeness of the maneuver, not the speed of its execution (Anokhin P.K., 1978; Solopov I.N., 2004). With coordinated work of individual systems, each of which includes its reserves, we can talk about a system of reserves of functioning systems, the level of which follows certain regularities of adaptive processes (Kulikov V. Yu., Pikovskaya N.B. 2011).

The results obtained indicate that during children's development, the indicators of vital lung capacity (FVC) tend to increase (table 1).

Table 1. *Age dynamics of respiratory function indicators in children living in the South Aral region (M±m) (n=125)*

age	gender	FVC	PEF	FEF-75	FEF-25
8	b (n = 11)	1.94 ± 0.08	3.77 ± 0.1	3.33 ± 0.1	1.26 ± 0.07
	g (n =18)	1.72 ± 0.08	4.06 ± 0.2	3.53 ± 0.2	1.36 ± 0.1
9	b (n = 10)	2.18 ± 0.08	4.49 ± 0.2	3.78 ± 0.2	1.33 ± 0.07
	g (n = 12)	1.85 ± 0.06	4.24 ± 0.1	3.86 ± 0.1	1.42 ± 0.1
10	b (n = 11)	2.34 ± 0.07	4.91 ± 0.2	4.23 ± 0.1	1.54 ± 0.1
	g (n = 14)	2.07 ± 0.07	5.17 ± 0.1	4.31 ± 0.2	1.76 ± 0.01

Note: g – girls, b – boys, FVC – forced vital capacity (liters); FEF-75 – forced expiratory flow at 75% of FVC (liters/second); FEF-25 – forced expiratory flow at 25% of FVC (liters/second), PEF – peak expiratory flow (liters/second)

During the conducted research, it was found that in boys aged 6 and 7 years, the FVC values were 1.90 ± 0.07 L and 1.93 ± 0.02 L respectively. The greatest increase in FVC was observed in children aged 9 and 10 years, with boys showing FVC values of 2.18 ± 0.08 L and 2.34 ± 0.07 L ($p < 0.001$) respectively.

Analysis of the data revealed that in girls aged 6 and 7 years, the FVC values were 1.60 ± 0.04 L and 1.62 ± 0.08 L respectively. The highest increase in FVC was observed in girls aged 9 and 10 years, with absolute FVC values of 1.85 ± 0.06 L and 2.07 ± 0.07 L ($p < 0.001$) respectively. In girls aged 10 years, the FVC was significantly higher at 2.07 ± 0.07 L ($p < 0.001$) compared to girls aged 6 years and not significantly different from girls aged 8 years ($p > 0.05$).

Examination of the patency of various parts of the tracheobronchial tree showed that in boys, there is a tendency towards increased bronchial patency with age. In boys aged 9 and 10 years, the patency of large bronchi (FEF-75) was 3.78 ± 0.2 L/s and 4.23 ± ± 0.1 L/s respectively compared to 3.33 ± 0.1 L/s for boys aged 7 and 8 years (respectively) ($p < 0.001$). In girls aged 9 and 10 years, the absolute values of FEF-75 were significantly increased to 4.31 ± 0.2 L/s compared to values of 3.48 ± 0.2 L/s and 3.53 ± 0.2 L/s in girls aged 7 and 8 years ($p < 0.001$).

It should be noted that the absolute values of small airway flow rates (FEF-25) in boys aged 9 and 10 years were significantly higher at 1.33 ± 0.07 and 1.54 ± 0.1 L/s, respectively, compared to boys aged 6–8 years ($p < 0.05$). As for girls, in the 9–10 age group, small airway flow rates (FEF-25) were significantly increased to 1.42 ± 0.1 and 1.76 ± 0.01 L/s ($p < 0.001$) compared to girls aged 7–8 years, and significantly higher than the 1.23 ± 0.1 L/s in girls aged 6 years ($p < 0.001$).

It is known that the movement of airflow during breathing is associated with a considerable expenditure of energy by the respiratory muscles. During inhalation, the elastic resistance of the lungs and chest tissues, the elastic resistance of the organs in the chest and abdominal cavities moving during breathing, as well as the resistance of the tracheobronchial tree have to be overcome (Kabirova E. I., 1989; Kuznetsova T. D., 1983; Kuznetsova T. D., 1986). Since muscular activity is the most powerful natural stimulus for breathing, we attached great importance to the dynamics of ventilation parameters after light physical exertion on the subjects (Garkavi L. Kh., Glanz S., 1999; Kabirova E. I., 1989; Kuznetsova T. D., 1983). Impulses from the sensorimotor cortex to the working muscles simultaneously have a direct influence on the respiratory center through corticobulbar pathways. In addition, breathing is stimulated by afferent impulses coming from the proprioceptors of the working muscles (Kuznetsova T. D., 1986). As soon as muscular load is initiated, breathing becomes faster and deeper. At the same time, the variability of ventilation parameters increases, which is apparently related to the different individual sensitivity of chemoreceptors and the respiratory center to humoral factors regulating breathing, as well as to the different intensity of metabolic processes in children of the same calendar age (Matyskin A. V., 2006; Ustyushin B. V., Istomin A. V., 1996).

All examined children show a relatively favorable dynamic of maximal lung ventilation (MLV) after the performed load: at 8 years old, it is 98.8%, at 9 years old, it is 106.8%, and at 10 years old, it is 102.4% of the resting level. If the testing of MLV in the first 60 seconds of the recovery period reveals that its value has not changed or has decreased but has not reached zero, then the performed load is considered relatively adequate. Such changes in the respiratory system are observed in examined 8–9-year-old children. In examined 10-year-old children, the response to this load is favorable, and adaptation to it occurs without additional strain on the external respiratory system, without signs of respiratory muscle fatigue.

It is well known that static and dynamic lung volumes increase with the age of children. This increase is provided by greater lung compliance with increasing age and the ability of muscles to produce maximum changes in thoracic cavity volume. Periods of maximal growth in these indicators are noted between 5 and 7 years old, i.e., at the age of 6 years, due to the predominance of the process of airway expansion over their elongation, bronchial resistance decreases intensively, breathing rates increase, and, accordingly, dynamic lung volumes increase. Under conditions of rest and breathing with atmospheric air, the functional indicators of the examined children correspond to age norms.

However, the respiratory reserve after performing the MLV test in these children falls into the category of high values. This fact, during the examination of the external respiratory system, is not considered a sign of any respiratory function-related disease but rather an individual reaction of the child to the load presented to them, indicating processes of adaptive response (Skoblina N. A., 2008; Ustyushin B. V., Istomin A. V., 1996). In this case, the activity of the autonomic systems, including the respiratory system, changes to create optimal conditions for supplying working muscles with energy and minimizing negative shifts in the body's internal environment that may arise due to metabolic processes in the muscles (Kuchkin S. N., 1988; Matyskin A. V., 2006; Skoblina N. A., 2008; Ustyushin B. V., Istomin A. V., 1996).

The identified relationships between the levels of lung ventilation function development and physical development are consistent and determined by the heterochrony and uneven maturation of each of the studied systems. Ventilation in 8–9-year-old children during exercise is provided solely by an increase in breathing rate, while in 10-year-old children, an increase in tidal volume is also slightly involved.

Therefore, considering the high pollution levels in the lower atmospheric layer in the Southern Aral Sea region, the observed increase in bronchial patency in children was interpreted by us as an undesirable reaction and one of the factors contributing to bronchopulmonary pathology development. Increasing bronchial patency in dusty atmospheric conditions is physiologically irrational. When assessing the levels of lung ventilation function development and physical development, it is important to consider the influence of environmental factors and heredity, especially in children who fall outside the average level of physical development. The use of developed assessment tables can help identify the nature and extent of deviations in the functional development of the respiratory system and physical development, determine ways and methods for their correction.

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