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Lung Function and Respiratory Muscle Strength in Obese in Children

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Background. *It is known that obesity may influence the state of respiratory function and it is associated with a number of diseases of the respiratory system. Obesity in itself, even in the absence of other known causes, can cause a feeling of shortness of breath at rest. At the same time, the cardinal symptom of respiratory muscle weakness is shortness of breath, which promotes the reduction of exercise tolerance. At the moment the problem state of respiratory function and respiratory muscles in children with different degrees of obesity is relevant and understudied.* ***Aim***. *Investigation of lung function and respiratory muscle strength in obese in children.* ***Methods***. *46 children with obesity were examined, with a prevalence of obesity of mixed origin with progressive, aged 7 to 16 years. We evaluated the lung function and strength of respiratory muscles in the form of maximum inspiratory pressure at the mouth (MIP), maximal expiratory pressure at the mouth (MEP) and nasal inspiratory pressure in the sniff-test (SNIP).* ***Results***. *The children with obesity complained of dyspnea. The respiratory muscle dysfunction observed in the form of reduction of its forces. Reduced respiratory muscle strength (≤ 80% of the norm) was in 44% of patients on the MIP and 38% on the MEP and was increased with increasing body mass index.* ***Conclusion***. *Children with obesity need to monitor the lung function and evaluate the strength of the respiratory muscles for early detection of functional disorders of the respiratory system.*

Key words: *children, obesity, lung function assessment, respiratory muscle strength.*

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JUSTIFICATION

The steady growth of obesity among adults and children is an urgent medical and social problem of the modern civilization. Obesity is one of the most common childhood chronic illnesses: 22 million children around the world suffer from it [1]. In many countries, the prevalence of obesity among children in the past 20 years has dramatically increased: thus, in the United States and Japan, the number of obese children has increased from 12% to 21% [2]. The increase in body weight is observed among children of both sexes and all ethnic and socioeconomic groups [3].

According to epidemiological studies conducted in Russia in 2005-2006 which included information on 10 223 adolescents aged 12-17 years, the incidence of overweight in students of

6-11 grades was 12% [4]. Indicators of research groups from Saratov and Orenburg demonstrate the prevalence of overweight (including obesity) in 11% and 7% of students aged 6-16 and 7-17 years, respectively [5, 6].

We know that children with obesity have a diabetes development risk, metabolic syndrome risk, and complications of the cardiovascular system [4, 7-9]. In addition, it is proven that obesity affects the state of respiratory function and is interconnected with a number of respiratory system diseases (bronchial asthma; obstructive sleep apnea syndrome, OSAS) [10]. From an epidemiological point of view, an increase in body mass index (BMI) is associated with increased prevalence of persistent asthma [11]. In 10-23% of children obesity was the primary factor in the development of OSAS[12]. Research on OSAS usually indicates that snoring and other symptoms of disordered breathing during sleep occur in obese children 2-3 times more frequently [13].

Obesity in children can be unreflected in spirometry indexes, but it can lead to their violations [14]. In case of obesity in children, the functional residual capacity of lungs can be reduced and the diffusion capacity may moderately decrease. There are also cases of reducing the proportion of a person's vital capacity so that they can expire in the first second of forced expiration (FEV_1/ FVC) with increasing BMI [15]. Overweight in children may be associated with a decrease in lung volumes [16].

Obesity by itself, even in the absence of other known causes, can cause the sensation of breathlessness at rest. The prevalence of breathlessness symptoms increases with body mass index or waist circumference [17, 18]. At the same time, breathlessness is the cardinal symptom of respiratory muscle weakness, contributing to a decrease in exercise tolerance. The range of diseases and conditions in which there is a weakness of the respiratory muscles is very wide. In most cases, the cause of respiratory muscles weakness are metabolic, inflammatory and degenerative changes that lead to dysfunction of respiratory muscles, and nervous system or neuromuscular junctions. In adults, there is a decrease in respiratory muscle strength in case of Pickwick's syndrome [10].

Expiratory muscle weakness is associated with ineffective cough and worsening of pulmonary clearance. It may cause repeated atelectasis or lower respiratory tract infections. The failure of the inspiratory muscles causes problems when using metered-dose aerosol inhalers: it is known that at low inspiratory airflow, availability of medicines is reduced.

Currently, the problem of state of respiratory function and respiratory muscle strength in children with different degrees of obesity is relevant and understudied.

Objective: To assess the state of ventilation function and respiratory muscle strength in children with obesity.

METHODS

Work design is a study of series of cases of obesity in children. Participants in the study were divided into groups according to the degree of obesity in order to analyze the state of ventilation function and respiratory muscle strength at different pathology severities.

Eligibility criteria: the study included children aged 7-15 years of both genders with obesity of mixed origin.

Conditions: the study was carried out in 2013-2014 in Perm based on the endocrinology department of the City Children's Clinical Hospital №15.

Description of medical intervention: clinical examinations and study of the ventilation function state and respiratory muscle strength were carried out.

The main outcome of the study: characterization of respiratory function state and respiratory muscle strength in obesity, including taking into account the degree of obesity.

During the clinical examination of patients, we analyzed outpatient cards, case histories and other anamnestic data. Physical inspection with in-depth examination of the respiratory system was conducted.

Physical development (weight, height, and weight-height accordance) was evaluated using centile tables respectively to the gender and age of children [19]. To verify obesity, BMI was calculated using the formula:

BMI = weight (kg) / height (m)

Diagnosis of obesity was determined using the standard BMI tables at excess of body mass index higher than the 95th percentile for a given gender and age of children [19, 20].

Subgroup analysis: The state of ventilation function and respiratory muscle strength, depending on the degree of obesity, were studied. Investigations of respiratory muscle strength in a subgroup of children who complained on the shortness of breath during exertion, were conducted. A calculation of body weight excess (in %) and the degree of obesity was determined in accordance with the recommendations of Y.A. Knyazev (1981):

- class I obesity – body weight excess is 15-29.5% of the perfect by height, age and gender a.o. adipose tissue;
- class II obesity - body weight excess is 30-49%;
- class III obesity - body weight excess is 50-99%;
- class IV obesity - body weight excess is 100% or more.

The 50th percentile was taken for ideal weight for each age and sex [21].

Exclusion criteria: bronchial asthma, chronic bronchopulmonary diseases, neuro- and myopathies, obstructive diseases of the nasal cavity (for sniff-tests).

Software and basic work methods. In order to assess the respiratory function, a spirographic research was carried out on the Spiro USB diagnostic complex using the SPIDA (UK) software. We recorded the flow-forced expiratory volume curve and calculated lung volumes and speed indications. To assess bronchial permeability, we considered the following groups of indicators:

- lung volume indicators: FEV_1, FVC;
- comparative figures: the ratio of FEV_1/ FVC.

The strength of respiratory muscles in the form of maximum inspiratory pressure at the level of the oral cavity (MIP), maximum expiratory pressure at the level of the oral cavity (MEP) and sniff-test nasal inspiratory pressure (SNIP) were assessed on the MicroRPM (Respiratory Pressure Meter; Micro Medical Ltd, United Kingdom) device. MicroRPM was used with the Puma software. The measurement results were evaluated in inches of the water column and the percentage to the individual standards. MIP index was determined by measuring the maximum static pressure at the mouth level, which the patient created with his/her airway closed during maximum inhalation; MEP index, respectively – during the maximum exhalation. During the test, patients were in a sitting position; to prevent air leakage, a nose clip was used. To determine MEP, patients made the most strong and fast exhaling after taking a maximum deep breath; respectively, to determine the MIP - the most strong and fast breath after a maximum exhalation. The result was calculated after 5 attempts for the inhalation and exhalation with intervals between attempts of at least 1 minute in order to prevent muscle fatigue. Attempts stopped after reaching differences between the three maximum values of less than 20%. Maximum pressure was registered.

Due to the absence in the literature of references to the national formula or standards of reference values for interpreting the results, the S. Wilson linear regression equation was taken as a basis [22]. Corresponding formulas for the individual calculating are shown in Table 1. The results of each patient were further compared with the standards, calculated according to these formulas.

Table 1. Standard MIP and MEP indicators

Categories of patients	MIP, cm of water column	MEP, cm of water column
Boys 7-17 years	44,5 + 0,75 × weight	35 + 5,5 × age
Girls 7-17 years	40 + 0,57 × weight	24 + 4,8 × age

Note. MIP - maximum inspiratory pressure at the mouth, MEP - maximum expiratory pressure at the mouth.

During SNIP measuring the patient was in a sitting position; the sensor was located in one nostril, completely blocking it: series of maneuvers on the level of the functional residual lung capacity was performed at intervals of not less than 30 seconds. After a normal exhalation, the patient had to take a breath with the greatest possible effort through the free nostril in the absence of air leakage through the lips: thus the peak pressure in the nasopharyngeal region was created. Determination of SNIP is an informative method of assessing the strength of the inspiratory muscles. To obtain reproducible results, the patient made 10 attempts.

Obtained results were compared with existing standards, calculated according to the corresponding formulas (Table 2)[22].

For each child, the individual percentage of deviation from the norm in all three indicators was calculated.

Table 2. Standard SNIP indexes

Categories of patients	SNIP, cm of water column.	
	Average value	The lower border of norm
Boys 6-17 years	70,0 + 0,30 × age	Average 39.9
Girls 6-12 years	92 ± 22	-
Girls 13-16 years	97 ± 26	-

Note. SNIP - nasal inspiratory pressure in the sniff-test.

Ethical review. The study was conducted according to the principles of the Helsinki Declaration of the World Medical Association - "Ethical principles for medical research involving human subjects". All patients included in the research project gave informed consent to participate in it. The study protocol was discussed at a meeting of the local ethics committee of the SBEI HVE “E.A. Wagner PSMA”, by a decision of which it was approved (Protocol № 51 from 06.26.2013).

Statistical analysis. Statistical analysis was performed using Statistica 7.0. *The sample size was not calculated preliminarily.* To describe the quantitative traits with a normal distribution, we calculated the mean value (M), standard deviation (σ), standard error of the mean (m); for qualitative traits - the absolute frequency of the appearance of a trait (the number of studied), the frequency of the appearance of a trait (%) and 95% confidence interval. In case of abnormal distribution, interquartile range from the 25th to the 75th percentile was used. Quantitative estimation of the linear relationship between two random values was calculated using Spearman rank correlation coefficients (r). The difference with $p < 0,05$ was considered statistically significant.

RESULTS

Participants. The study included 46 children aged from 7 to 15 years with obesity of mixed origin with progressive course prevalence. There were 29 boys and 17 girls. The average age of this group of children was 11 ± 1,7 years.

BMI exceeded the 95th percentile in 16 (35%) children, and the 97th percentile - in 30 (65%). The average BMI of the surveyed children was 28,3 ± 5,34. They were divided into 3 groups depending on the degree of obesity. Children who complained on shortness of breath on exertion, were isolated in a separate subgroup.

Class I obesity was diagnosed in 2 (4.3%) children, class II - in 12 (26,1%), class III - in 19 (41,3%), class IV – in 13 (28.3%). 16 (35%) children complained about constant breathlessness during exertion; two (4%) patients noted the appearance of dry cough during exercising, the same number admitted active tobacco smoking.

Pathology of the cardiovascular system in the form of I degree arterial hypertension was observed in 11% of patients with obesity and shortness of breath.

Key results

Indicators of ventilation function: reduction of FEV_1 less than 80% - in 2.2% of children, reduction of FVC less than 80% - in 13%, the ratio of FEV_1 / FVC less than 90% - in 2.4%.

The average relative values of respiratory muscle strength (% deviation from the norm) in general in obese children group: MIP 101,4 ± 4,05 cm of water column, MEP 89,8 ± 3,69 cm water column, SNIP 76 ± 4,35 cm water column. In 28% of the observed, a decline in MIP (≤ 80% of the norm), in 33% - a reduction of MEP (≤ 80% of the norm), in 67% - a reduction of SNIP (≤ 80% of the norm). Indicators of respiratory muscle strength depending on the degree of obesity are presented in table 3.

Table 3. Indicators of ventilation function and respiratory muscle strength in children with different obesity classes (in % of the norm, except for the ratio of FEV_1 / FVC)

Index*	**MIP**	**MEP**	**SNIP**	**FEV_1**	**FVC**	**FEV_1 / FVC**
Obesity I-II	114 [103.25; 119.25]	95.5 [88; 112.25]	61 [52.5; 103]	100 [95; 105,75]	89 [81.25; 96,75]	116 [108.75; 117]
Obesity III	108 [80; 122]	89 [59; 101]	70 [52; 82.5]	94 [88; 105.5]	88 [78; 94]	110 [107; 117]
Obesity IV	94 [72; 110]	88 [75; 110]	65 [50; 94]	104 [97; 109]	94 [87; 97]	112 [108; 118]

Note. MIP - maximum inspiratory pressure at the level of the oral cavity, MEP - maximal expiratory pressure at the level of the oral cavity, SNIP - nasal inspiratory pressure in the sniff-test FEV_1 - Forced expiratory volume in the first second, FVC - forced vital capacity.
Indicators are presented as median [25th and 75th percentile].

In the subgroup of children (n = 16) we observed constant breathlessness during exertion, a reduction (≤ 80% of the norm) of MIP in 44%, a decrease in MEP (≤ 80% of the norm) – in 38%, a decrease in SNIP (≤ 80% of the norm) – in 94%.

The relationship between the parameters of respiratory muscle strength and spirometric data is defined: MEP index correlated with FVC (r = 0,31; p <0,05), weakly correlated with FEV_1 (r = 0,29; p <0,05); BMI inversely correlated with MIP (r = -0,41; p <0,05).

Additional results of the study were not found, adverse events were not fixed.

DISCUSSION

Summary of the main results of the study. We observed complaints of shortness of breath on exertion in 35% of the surveyed children with obesity without serious diseases of the cardiovascular and respiratory systems, which may be related to their general untrained state and the state of the cardiovascular system, as well as to respiratory muscle dysfunction and changes in the functional state of the respiratory system. We can try to estimate the severity of breathlessness in these patients on the dyspnea scale of the Medical Research Council (UK), which is mainly used in adult patients. Given the possible complications, in children with obesity and complaints of shortness of breath, it is advisable to conduct a comprehensive in-depth examination of the cardiovascular or respiratory system (monitoring of the respiratory rate indicators, minute volume of respiration, heart rate, blood pressure, electrocardiogram before and after exercise).

In the presented study, evaluation of respiratory muscle strength by determining the MIP, MEP and SNIP as one of the most studied and proven in clinical diagnostic approaches, was used. To evaluate the respiratory muscles in children, other non-invasive methods can be applied: inspiratory reserve and tension time index of the diaphragm determination, inductive plethysmography of thoracoabdominal movements, surface electromyography of the respiratory muscles, the definition of MEP and MIP during children's cry [23]. The study stated that the dysfunction of respiratory muscles in form of reduction of its strength (≤ 80% of the norm) is observed in obesity with complaints of shortness of breath: in 44% of the patients – of MIP, in 38% - of MEP with the increase while BMI's growth.

Discussion of the main results of the study. The established correlations indicate that the decline in expiratory muscle strength, possibly is associated with a decrease in lung volumes, including due to the deposition of fat tissue. In spirographic study, in 13% of obese children, declines in FVC were noted. The strength of the respiratory muscles decreased with the increasing BMI.

As can be seen from table 3, MEP decline was most pronounced in the III-IV obesity classes. To a lesser extent decreased the MIP index. SNIP index was reduced by 1/3 and more in all the obesity classes. However, it must be taken into consideration that one of the sniff-test shortcomings is their arbitrary character - dependence of the result on the will of the patient. These tests depend on the patency of the upper airway, and are almost unavailable in the complete obstruction of the nose. Dysfunction of expiratory respiratory muscles in obese children may reduce the effectiveness of cough, which in its turn will contribute to the secretion delay in the bronchi, with further risk of atelectasis and pneumonia. Reduced strength of inspiratory respiratory muscles is able to reduce the effectiveness of inhalation therapy, for example, in patients with obesity and asthma [16, 22].

Limitations of the study are associated with a small number of studied patients with obesity and with predominance of more severe degree of obesity.

Conclusions. Clinical management of obese patients tactics should focus on in-depth examination to diagnose comorbid conditions such as hypoventilation syndrome and obstructive sleep apnea syndrome. In the presence of clinical symptoms of the latter, polysomnography night's sleep observation is needed.

Children with obesity and shortness of breath in case of MIP / MEP rates reduction at normal levels of FVC and FEV_1 should undergo a detailed examination and spirometric body plethysmography (to avoid restrictive violations). It is also necessary to assess the level of blood oxygenation ($SatO_2$) including the night's sleep indexes; to examine the blood gases to identify daytime hypercapnia ($PaCO_2$ > 45 mmHg) or hypoxemia (PaO_2 <70 mmHg); to determine the level of plasma bicarbonate HCO^{3-}.

Differential diagnosis of obesity requires the exclusion of other states, as well as alternative causes of hypoventilation.

Brief practical recommendations

1. Respiratory muscle strength at the level of the oral cavity by the MicroRPM (Respiratory Pressure Meter) measurement is non-invasive, safe and can be conducted in children on both outpatient basis (in the laboratories of functional diagnostics, in the clinic), and at hospital.
2. For obese children it is expedient to carry out the state of respiratory function monitoring and respiratory muscles strength evaluation (indicators MEP and MIP) to reveal respiratory system violations.
3. It is advisable to carry out the tests assessing respiratory muscle strength indicators at the level of the oral cavity in comprehensive differential diagnosis of breathlessness at children.

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CONFLICT OF INTEREST

The authors have indicated they have no conflict of interest relevant to this article to disclose.

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REFERENCES

1. Deckelbaum R.J., Williams C.L. Childhoodobesity: the health issue. *Obes Res*. 2001; 9 (Suppl. 4): 239–243.
2. Hedley A.A., Ogden C.L., Johnson C.L., Carroll M.D., Curtin L.R., Flegal K.M. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA*. 2004; 291: 2847–2850.
3. Dietz W.H., Robinson T.N. Clinical practice. Overweight children and adolescents. *N Engl J Med*. 2005; 352: 2100–2109.
4. Akhmedova R.M., Sofronova L.V. Obesity and metabolic syndrome in childhood: a modern view on the problem. *Voprosy diagnostiki v pediatrii = Diagnostics in pediatrics*. 2012; 4 (1): 13–19.
5. Aver'yanov A.P. *Ozhirenie u detei i podrostkov: kliniko-metabolicheskie osobennosti, lechenie, prognoz i profilaktika oslozhnenii. Avtoref. dis. ...dokt. med. nauk* [Obesity

in Children and Adolescents: the Clinical and Metabolic Characteristics, Treatment, Prognosis and Prevention of Complications. Author's abstract]. Saratov. 2009. 53 p.

6. Lebed'kova S.E., Ignatova T.N., Trusova O.Yu., Vivtanenko T.V., Roshchupkin A.N. On the metabolic syndrome in children and adolescents with obesity. *Pediatriya = Pediatrics*. 2010; 89 (2): 151–155.
7. Boikov V.A., Kobyakova O.S., Deev I.A., Kulikov E.S., Starovoitova E.A. Status of respiratory function in patients with obesity. *Byulleten' sibirskoi meditsiny = Bulletin of Siberian medicine*. 2013; 12 (1): 86–92.
8. Davidovich V.V. *Funktsiya vneshnego dykhaniya u patsientov s morbidnym ozhireniem. Lechebno-profilakticheskie voprosy* [Respiratory Function in Patients with Morbid Obesity. Treatment and Prevention Issues]. 2013. P. 34–38.
9. Krasnoperova O.I. Clinical and metabolic characteristics of various degrees of obesity in children. *Permskii meditsinskii zhurnal = Perm Medical Journal*. 2012; 29 (2): 99–105.
10. Avdeev S.N., Nuralieva G.S. Obesity hypoventilation syndrome. *Pul'monologiya i allergologiya = Pulmonology and Allergology*. 2006; 3: 10–14.
11. Maiolo C., Mohamed E.I., Carbonelli M.G. Body composition and respiratory function. *Acta Diabetol*. 2003; 40 (Suppl. 1): 32–38.
12. Erler T., Paditz E. Obstructive sleep apnea syndrome in children: a state-of-the-art review. *TreatRespir Med*. 2004; 3: 107–122.
13. Young T., Peppard P.E., Gottlieb D.J. Epidemiology of obstructive sleep apnea: a population health perspective. *Am J RespirCrit Care Med*. 2002; 165: 1217–1239.
14. Marcus C.L., Curtis S., Koerner C.B., Joffe A., Serwint J.R., Loughlin G.M. Evaluation ofpulmonary function and polysomnography in obese children and adolescents. *Pediatr Pulmonol*. 1996; 21: 176–183.
15. Pistelli R., Brancato G., Forastiere F. Population values of lung volumes and flows in children: effect of sex, body mass and respiratory conditions. *EurRespir J*. 1992; 5: 463–470.
16. Inselman L.S., Milanese A., Deurloo A. Effect of obesity on pulmonary function in children. *PediatrPulmonol*. 1993; 16: 130–137.
17. Jubber A.S. Respiratory complications of obesity. *Int J ClinPract*. 2004; 58: 573–580.
18. Sampson M.G., Grassino A.E. Load compensation in obese patients during quiet tidal breathing. *J Appl Physiol*. 1983; 55: 1269–1276.

19. Namazova-Baranova L.S., Resnenko A.B. *Ozhirenie: karmannyi spravochnik pediatra* [Obesity: a pocket guide pediatrician]. Moscow, Pediatr", 2012. 23 p.
20. Sofronova L.V.,Trefilov R.N. *Metody otsenki narushenii fizicheskogo i polovogo razvitiya u detei i podrostkov: metodicheskie rekomendatsii dlya vrachei-pediatrov* [Methods of evaluation of disorders of physical and sexual development in children and adolescents: guidelines for pediatricians]. Perm, GBOU VPO «PGMA im. ak. E.A. Vagnera» Minzdrava Rossii, 2013. 45 p.
21. Koryukina I.P., Sofronova L.V., Trefilov R.N. *Metody otsenki fizicheskogo razvitiya i biologicheskoi zrelosti detei i podrostkov* [Methods of assessing physical development and biological maturity of children and adolescents]. Perm, GBOU VPO «PGMA im. ak. E.A. Vagnera» Minzdrava Rossii, 2007. 191 p.
22. Avdeev S.N. Qualification strength of the respiratory muscles in clinical practice. *Pul'monologiya i allergologiya = Pulmonology and Allergology*. 2008; 4: 12–17.
23. ATS/ERS Statement on Respiratory Muscle Testing, 2001. *Am J Respir Crit Care Med*. 2002; 166: 518–624.