The Correlation between Body Mass Index, Maximum Inspiratory Pressure, and Vital Capacity in Elementary School Children

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Abstract: This study aimed to assess the correlation between Body Mass Index (BMI), Maximum Inspiratory Pressure (MIP) and Vital Capacity (VC) of elementary school children aged 8-12 years old. A cross sectional study was conducted to measure BMI, MIP, and VC among children residing in Central Jakarta. Exclusion criteria included a history of surgery in the chest area, neuromuscular disease, and cardiorespiratory problems. 27 subjects, who were eligible for the study, were divided into two groups, classified as normal or abnormal BMI group. MIP and VC were measured by digital manometer and spirometer respectively. Data were analyzed by the T-test and Pearson test. The differences of MIP and VC value in the normal and abnormal BMI group was found tend to higher of MIP in normal BMI group, i.e. 75.71 + 12.83 and 70.55 +16.4, and higher of VC in normal BMI group, i.e. 1.69 ± 0.27 amd 1.91± 0.47(p=0.025). There was moderate positive correlated between BMI and VC (r= 0.652, p<0.001), in contrast between BMI and MIP (r= 0.352, P = 0.071). Children with normal BMI has higher VC, while the higher of BMI has correlation with the higher of VC.

1 INTRODUCTION

Childhood is the age span ranging from birth to adolescence. In this stage, children's growth and development status were rapidly emerging. The growth of the children can be measured by the Body Mass Index (BMI) as a reflection of their nutritional status. Nutritional Status divided by 3 classifications such as normal, underweight, overweight, and obesity. In 2012, it was reported that all over the world, more than 40 million children aged ≥5 years were overweight or obese. (da Jung and Schivinski, 2014)

Nowadays, obesity has become one major health issue in the world. Overweight and obesity has increased rapidly in populations and associated with several complications, such as hypertension, diabetes, psychosocial disorders which related to acceptance in the group, or removal of group activities, sleep apnea, and increased ventilatory demand. Obesity increased ventilatory demand which often accompanied by fatigue upon exertion and limitations to carry out some activities of daily living. (da Jung and Schivinski, 2014), which will lowered affected children's quality of life.

According to the physiology of respiratory function, obese people may have an altered ventilation distribution, with the risk of manifesting gas exchange abnormalities. There will be a reduction in spirometry test variables of functional residual capacity and expiratory reserve volume due to the presence of adipose tissue accumulation around the thoracic and abdominal surfaces. Furthermore, obesity will induce fat deposition in compartments, reduction of pulmonary compliance, damage to mechanical ventilation due to increased respiratory effort, potential inefficient respiration, and decreased ability to generate strength for breathing. On the other hand, underweight children have smaller muscle mass, which may affect the strength of respiratory muscle and diminishing lung capacity.

Respiratory function was influenced by the skeletal structure, respiratory muscle strength, and lung volume. Respiratory muscle strength can be

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measured by Maximum Inspiratory Pressure (MIP) and Maximum Expiratory Pressure (MEP). MIP interpreted the strength of diaphragm and inspiratory muscle, meanwhile, MEP interpreted the strength of the abdominal muscles and expiratory muscles. (Heinzmann-Filho et al., 2012)

Nevertheless, it is still controversial that obesity may generate a reduction in lung volumes and increased airway resistance. Many studies are conducted to seek any relationship between obesity and respiratory muscle strength, although without showing any conclusive results. Studies with children samples were also limited. (da Rosa et al., 2017). A study by Redding (2017) showed that there was a relationship between MIP and VC in early scoliosis children, but with no differentiation for each BMI classification. (Redding et al., 2017) Hence, in this study, we would like to assess the correlation between various BMI status and respiratory muscle strength along with vital capacity. We hypothesized that abnormal BMI will be lowering the MIP value and vital capacity (VC).

2 METHODS

A cross sectional study was conducted to analyze the Body Mass Index (BMI), Maximum Inspiratory Pressure (MIP), Vital capacity among healthy elementary children residing in Central Jakarta. The study was ethically approved by the Research Ethics Department of Cipto Mangunkusumo Hospital, Faculty of Medicine University of Indonesia. The inclusion criteria included children aged 8-12 years, meanwhile, the exclusion criteria included a history of surgery in the chest area and upper abdomen, chest deformities, history of neuromuscular disease, and other cardiorespiratory problems.

The subjects were screened and their anthropometric status was measured. The body weight was evaluated by digital portable device, body height was measured with shoorboard and BMI was calculated by dividing the weight by height in meters squared (kg/m2). It was then categorized into normal BMI and abnormal BMI based on the criteria legalized by the Ministry of Health of Indonesia.

Maximum Inspiratory Pressure was measured by a digital manometer (microrpm) with muller's maneuver. First, the subject was asked to inhale as much as possible meanwhile the maximum inspiration was measured in MIP. This examination was repeated 3 times and the highest value was recorded along with the difference between the highest and the lowest result <20%. (Heinzmann-Filho *et al.*, 2012). Vital capacity was measured by a spirometer. A comparison of MIP and Vital capacity between groups were analyzed by the Unpaired T-test and Pearson correlation test.

3 RESULTS

There were 27 subjects were enrolled in this study, 19 boys and 8 girls. The mean age was 9.67 ± 0.17 years old. 7 subjects with normal BMI and 20 subjects with abnormal BMI. Mean of BMI for the obesity, overweight and underweight groups was 25.43±0.76, 21.33±0.69 and 13.67±0.07 respectively.

MIP values in elementary school children within normal BMI was higher than in the abnormal BMI group (75.71 ± 12.83 and 70.55 ±16.41), but with no significant difference (p=0.358). Vital capacity in children with normal BMI and abnormal BMI was not statistically significant (1.69+ 0.27 vs 1.91 + 0.47, p=0.025).

Table 1. Comparison of BMI with MIP and VC.

	Normal BMI n= 7	Abnormal BMI n= 20	*p*-Value
MIP	75.71 ± 12.83	70.55 ±16.41	0.358
VC	1.69 ± 0.27	1.91± 0.47	0.025 *

*T test

BMI, body mass index; MIP, maximum inspiratory pressure; VC, vital capacity. *P <0.05.

The BMI value had a positive correlation with vital capacity (r= 0.652, p<0.001), but showed insignificantly very weak positive correlation with respiratory muscle strength (r=0.124, p=0.539). MIP value had an insignificantly weak correlation with lung vital capacity.

Table 2. Correlation between MIP, BMI, and VC.

	Pearson's correlation coefficient	p-value	n
BMI-MIP	0.124	0.539	27
BMI – VC	0.652	0.000*	27
MIP - VC	0.352	0.071	27

*pearson test

4 DISCUSSIONS

Obesity affects the respiratory system by several mechanisms, including direct mechanical changes due to fat deposition in the chest wall, abdomen, and upper airway. The function of the respiratory muscles may be impaired with increasing obesity, possibly due to the load imposed on the diaphragm. The observed dysfunction of the respiratory muscles can be partially explained by the increased resistance imposed by the presence of excess fatty tissue on the chest and abdomen, which causes mechanical disadvantage to these muscles. (Mafort *et al.*, 2016)

Respiratory muscle strength can be assessed by measuring MIP and MEP. (Mafort et al., 2016) In obese individuals, both MIP and MEP may be reduced. The impairment of respiratory muscles is multifactorial; there are ineffective muscle contractions and premature fatigue, indicating that the reduction in MIP and MEP may be due to distension of the diaphragmatic muscles, increased respiratory effort, and ineffective muscle biomechanics caused by fat deposition in the thoracic and abdominal regions. (Chlif M, Keochkerian D, Choquet D, Vaidie A, 2009; Arena R, 2014)

In the present study, we found that MIP values in elementary school children with normal BMI are higher than abnormal BMI values (75.71 + 12.83 and 70.55 +16.41, p=0.358). Weak positive correlation with respiratory muscle strength (r=0.124, p=0.539) was also revealed in our study as in the previous study. (Rosa and Schivinski, 2014) Another study has shown an increment of MIP in the adult obese group compared to the non-obese group. They explained there was an increment in thoracic impedance in obese adults due to fat deposition on the diaphragm. This may reduce the Functional residual capacity (FRC) and it requires high ventilation, hence it increases the respiratory force and pressure during ventilation. (Shinde et al., 2017) A negative correlation was also revealed from the study comparing MIP of obese women before and after gastrectomy surgery. (Weiner et al., 1998) A preliminary study used skeletal muscle mass index (SMI) correlated to respiratory muscle in sarcopenia patients. muscle index was determined as skeletal muscle mass, it was measured by bioelectrical impedance analysis. This study has shown positive correlations between MIP and SMI. This study probably more accurately predicts respiratory muscle function than BMI alone, but still, need further investigation. (Ro et al., 2015)

Individuals with obesity presented with a reduction in lung volume and capacity as compared to healthy individuals, which means that the presence of a restrictive respiratory pattern associated with obesity. There are several potential mechanisms by which BMI might lead to reduce VC, which was broadly divided into mechanical and inflammatory. (Liu et al., 2017)

Visceral adipose tissue influences circulating concentrations of interleukin-6, tumor necrosis factor alpha, leptin, and adiponectin, which are cytokines that may act via systemic inflammation to negatively affect pulmonary function.(Paralikar et al., 2012) As BMI continues to rise, the fat content rises gradually, Intra-peritoneal fat deposits and accumulation may impede the descent of the diaphragm during inspiration, which would affect the lung's breathing function.(Liu et al., 2017)

Vital capacity in children with normal BMI and abnormal BMI was insignificant difference (1.69+ 0.27 vs 1.91 + 0.47, p=0.358). However, BMI has positive correlation with vital capacity (r= 0.652, p<0.001). The previous study in Italian school children has shown a positive correlation between FVC and body weight. They hypothesized that weight behaves as an index of body growth and in turn increases the lung volume. In addition, BMI may not truly reflect adiposity, rather a simpler epidemiological measure. (Cibella et al., 2015) A study conducted in children 8-12 years of age reported children with higher BMI and larger waist circumference have the higher vital capacity. (Bekkers et al., 2015) A similar result also proved through a meta-analysis that there was no significant association between BMI and vital capacity in children and was negatively associated with FVC in adults. There was a slight increase in FVC in overweight or obese children but also increased risk of airway dysanapsis- a phenomenon in which an asymmetrical growth of the lungs and airways lead to higher FEV1 and FVC but with a more pronounced effect on FVC. Nevertheless, overweight and obese adults have lower vital capacity, this is probably due to BMI in adult only represents adiposity and not growth. (Forno et al., 2018)

We found only weak correlation between MIP and lung vital capacity. Previous studies in early-onset scoliosis children with no muscle weakness, MIP%, and MEP% were significantly correlated with FVC. (Redding et al., 2017) Another study showed anterior pelvic tilt position muscle alignment was better for increasing vital capacity, however no specific measurement of respiratory muscle strength was done by the researcher. (Jang and Lee, 2015) In neuromuscular disorder, FVC has been used to evaluate an intervention in patients. However, the result may also be affected by factors that are independent of respiratory muscle dysfunction and measuring MIP could be a complement to spirometry. Furthermore, MIP may be more sensitive than FVC for assessing respiratory muscle function since spirometry test results are influenced by many factors. (Schoser et al., 2017)

5 CONCLUSIONS

Children inspiratory muscle strength was influenced by their anthropometric status, as it is better in children with normal BMI. Obesity caused mechanical compression of the diaphragm, resulting in increased pulmonary resistance and reduction of pulmonary muscle strength.

Higher BMI increased the dimensions of the lung which is described by increased VC. In this study, there was no correlation between BMI and children's lung compliance. Further research with more subjects was recommended to produce a better result

REFERENCES

Arena R, C. L. 2014. 'Evaluation of cardiorespiratory fitness and respiratory muscle function in the obese population', Prog Cardiovasc Dis, 56, pp. 457–64.

Bekkers, M., Wijga, A., Gehring, U., Koppelman, G., de Jongste, J., Smit, H. and Brunekreef, B. 2015. BMI, waist circumference at 8 and 12 years of age and FVC and FEV1 at 12 years of age; the PIAMA birth cohort study. BMC Pulmonary Medicine, [online] 15(1). Available at: https://www.ncbi.nlm.nih.gov/pubmed/25896340 [Accessed 2 Sep. 2019].

Chlif M, Keochkerian D, Choquet D, Vaidie A, A. S. 2009. 'Effects of obesity on breathing pattern, ventilatory neural drive, and mechanics', Respir Physiol Neurobiol, 168, pp. 198–202.

Cibella, F., Bruno, A., Cuttitta, G., Bucchieri, S., Melis, M., De Cantis, S., La Grutta, S. and Viegi, G. 2015. An Elevated Body Mass Index Increases Lung Volume but Reduces Airflow in Italian Schoolchildren. PLOS ONE, [online] 10(5), p.e0127154. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4430514/ [Accessed 2 Sep. 2019].

Forno, E., Han, Y., Mullen, J., and Celedón, J. 2018. Overweight, Obesity, and Lung Function in Children and Adults—A Meta-analysis. The Journal of Allergy and Clinical Immunology: In Practice, [online] 6(2), pp.570-581.e10. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5845780/ [Accessed 2 Sep. 2019].

Heinzmann-Filho, J. P. et al. 2012. 'Normal values for respiratory muscle strength in healthy preschoolers and school children', Respiratory Medicine, 106(12), pp. 1639–1646. doi: 10.1016/j.rmed.2012.08.015.

Jang, S. and Lee, S. 2015. A comparison of vital capacity values and respiratory muscle activities on pelvic tilt position. Physical Therapy Rehabilitation Science, [online] 4(2), pp.108-114. Available at: http://www.jptrs.org/journal/view.html?doi=10.14474/ptrs.2015.4.2.108 [Accessed 2 Sep. 2019].

da Jung, R., and Schivinski, C. 2014. 'Assessment of respiratory muscle strength in children according to the classification of body mass index', Revista Paul Pediatr, 32(2), pp. 250–255. doi: 10.1590/0103-0582201432210313.

Liu, P. et al. 2017. 'Association between body mass index (BMI) and vital capacity of college students of Zhuang nationality in China : a cross-sectional study', 8(46), pp. 80923–80933.

Mafort, T. T. et al. 2016. 'Obesity: systemic and pulmonary complications, biochemical abnormalities, and impairment of lung function', Multidisciplinary Respiratory Medicine. Multidisciplinary Respiratory Medicine, pp. 1–11. doi: 10.1186/s40248-016-0066-z.

Paralikar, S. J. et al. 2012. 'Assessment of pulmonary functions in obese adolescent boys', 29(3). doi: 10.4103/0970-2113.99106.

Redding, G. et al. 2017. 'Maximal respiratory muscle strength and vital capacity in children with early-onset scoliosis', Spine, 42(23), pp. 1799–1804.

Redding, G., Mayer, O., White, K., Bompadre, V., Emerson, J., Krengel, W. and Campbell, R. 2017. Maximal Respiratory Muscle Strength and Vital Capacity in Children With Early Onset Scoliosis. SPINE, [online] 42(23), pp.1799-1804. Available at: https://www.ncbi.nlm.nih.gov/pubmed/28858191 [Accessed 2 Sep. 2019].

Ro, H., Kim, D., Lee, S., Seo, K., Kang, S. and Suh, H. 2015. Relationship Between Respiratory Muscle Strength and Conventional Sarcopenic Indices in Young Adults: A Preliminary Study. Annals of Rehabilitation Medicine, [online] 39(6), p.880. Available at: https://www.e-arm.org/journal/view.php?doi=10.5535/arm.2015.39.6.880 [Accessed 2 Sep. 2019].

Rosa, G. and Schivinski, C. 2014. Assessment of respiratory muscle strength in children according to the classification of body mass index. Revista Paulista de Pediatria, [online] 32(2), pp.250-255. Available at: https://www.ncbi.nlm.nih.gov/pubmed/25119758 [Accessed 2 Sep. 2019].

da Rosa, G. J. et al. 2017. 'Predictive equations for maximal respiratory pressures of children aged 7–10', Brazilian Journal of Physical Therapy, 21(1), pp. 30–36. doi: 10.1016/j.bjpt.2016.04.002.

Salome CM, King GG, Berend. N. 2010. 'Physiology of obesity and effects on lung function', J Appl Physiol, 108(1), pp. 206–11.

Schoser, B., Fong, E., Geberhiwot, T., Hughes, D., Kissel, J., Madathil, S., Orlikowski, D., Polkey, M., Roberts, M., Tiddens, H. and Young, P. 2017. Maximum inspiratory pressure as a clinically meaningful trial endpoint for neuromuscular diseases: a comprehensive review of the literature. Orphanet Journal of Rare Diseases, [online] 12(1). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5353799/ [Accessed 2 Sep. 2019].

Shinde, V., Phatale, R., Shinde, U., Waghmare, N. 2017. The impact of obesity on respiratory muscle strength in adults. International Journal of Contemporary Medical Research, [online] 4(9), pp 1879-1882. Available at: https://www.ijcmr.com/uploads/7/7/4/6/77464738/ijcmr_1655_v1_1.pdf [Accessed 2 Sep. 2019].