Baran Joanna[1], Czenczek-Lewandowska Ewelina[1], Weres Aneta[1], Baran Rafał[2], Leszczak Justyna[1], Rusek Wojciech[2,3], Adamczyk Marzena[2,3], Pop Teresa[1]

[1] Instytut Fizjoterapii Wydział Medyczny Uniwersytet Rzeszowski
[2] Centrum Rehabilitacji Rehamed-Center w Tajęcinie
[3] RehaKlinika, Rzeszów

BODY COMPOSITION, BODY FAT DISTRIBUTION AND RESPIRATORY FUNCTION IN YOUNG ADULTS
SKŁAD MASY CIAŁA, ZAWARTOŚĆ TKANKI TŁUSZCZOWEJ I FUNKCJA ODDECHOWA U MŁODYCH DOROSŁYCH

Key words: Body Composition, Body Mass Index, Intra-Abdominal Fat, Spirometry, Waist-Hip Ratio.

Słowa kluczowe: Skład masy ciała, BMI, tkanka tłuszczowa wisceralna, spirometria, WHR.

ABSTRACT

Background and Aims: The increased fat content may predispose to numerous diseases e.g. diabetes, obesity and vascular conditions. The aim of the study was to evaluate the differences in respiratory parameters in young adults depending on the body composition.

Methods and Results: The study group consisted of 135 healthy, non-smoking subjects aged 18-30 yrs. Subjects were examined by tests: body composition evaluated using bioimpedance, anthropometric measurements, spirometry and questionnaire. The results were statistically analyzed using Spearman's rank correlation coefficient and Mann-Whitney test adopting statistically significant value at $p < 0.05$.

In women, there was a significant statistical correlation between forced vital capacity (FVC) and body mass as well as body fat percentage (BFP), Visceral Fat Rating and body mass index (BMI). Women with higher body mass and body fat had better results of FVC parameter. Also single correlations between forced expratory volume in one second (FEV1%) and body mass as well as forced inspiratory vital capacity (FIVC) and waist – hip ratio (WHR) were found. In the population of males strong correlations between breathing parameters and body mass, free – fat mass (FFM) or BMI, and between FIV1% and WHR were found.

Conclusion: Women with higher body mass and body fat obtained better FVC parameters while lower FEV1%. Higher values of WHR condition better forced inspiratory vital capacity (FIVC) in women and men.

STRESZCZENIE

Wstęp: Podwyższona zawartość tłuszczu może predysponować do wielu chorób jak np. cukrzycy, otyłości czy chorób układu naczyniowego. Szczególnie niebezpieczna jest podwyższona zawartość tkanki tłuszczowej wisceralnej, która powoduje otłuszczenie narządów wewnętrznych (często przy prawidłowym wskaźniku BMI), a tym samym upośledzenie ich funkcji.

Celem badań była ocena czy występują różnice w parametrach oddechowych u młodych dorosłych w zależności od składu masy ciała.

Metoda i wyniki: Grupę badaną stanowiło 135 osób w wieku 18-30 lat. U osób tych dokonano oceny składu ciała metodą bioimpedancji elektrycznej, wykonano pomiary antropometryczne, badanie spirometryczne oraz zastosowano autorską ankietę.

Wyniki opracowano statystycznie stosując współczynnik korelacji rang Spearmana oraz test Manna-Whitneya przyjmując $p<0,05$ za wartość istotną statystycznie.

U kobiet, stwierdzono znamienne statystycznie zależności pomiędzy FVC i masą ciała, FAT%, Visceral Fat Rating oraz BMI. Kobiety z wyższą masą ciała oraz zawartością tkanki tłuszczowej mają lepsze wyniki dla parametru FVC. Wykryto również pojedyncze korelacje dotyczące FEV1% i masy ciała oraz FIVC i WHR.

W zbiorowości mężczyzn stwierdzono silne korelacje między parametrami oddechowymi a masą ciała, FFM czy BMI oraz między FIV1% a WHR.

Wnioski: Kobiety z wyższą masą ciała oraz zawartością tkanki tłuszczowej w organizmie osiągają lepsze wyniki parametrów FVC natomiast niższe FEV1%. Wyższe wartości wskaźnika WHR warunkują lepsze wyniki natężonej pojemności wdechowej (FIVC) u kobiet i mężczyzn.

Introduction

One of the biggest public health problems and challenges of modern medicine is overweight and obesity among younger and younger age groups. According to the data from the World Health Organization reports, in 2016 overweight and obesity affected globally as many as 41 million children under 5 yrs, 340 million school-age children and almost two billion adults [1].

A lot of papers in literature illustrate how important is to maintain a normal body mass indices is in childhood and adolescence, since they can directly affect the current and future state of the functioning of internal organs and the whole body [2]. As Johnson and Beattie emphasize, the analysis of the body weight composition in children should be considered as a standard test in medical practice, because the measurements of weight and body height are not sufficient to assess their development [3].

The accumulation of fat in the body most frequently promotes the development of chronic diseases, i.e. atherosclerosis and hypertension, which in turn predispose to serious cardiovascular events [4]. It was also proved that excess body fat in the abdomen causes the secretion of several protein compounds that reduce the body's sensitivity to insulin, which can lead to the development of type 2 diabetes in adulthood [5]. Vitezova suggests a possible compound of lower vitamin D status and higher fat mass percentage in eldery [6]. In addition, obesity induced by improper diet, low physical activity are considered the cause of up to 20% of all cancers in adulthood [7]. As revealed, obese people have also higher risk of respiratory symptoms. According to the Manuel and co-authors, chronic respiratory failure develops in even 1/3 of people with obesity. Their study showed that the presence of visceral adipose tissue correlated with this process to a largest extend [8]. These results indicate that respiratory function may correlate with the body mass and body mass composition. Described topic was widely analyzed by Wannamethee, however his study was focused on the distinct effects of fat distribution and body composition on lung function in elderly men [9].

Considering the fact that overweight and obesity start to affect increasingly in younger population, it is particularly important to make an early assessment of body composition indicators in young people with normal weight, without diagnosed chronic diseases in relation to different health parameters. The aim of the study was to assess the occurrence of differences in respiratory parameters depending on body composition in young adults.

Methods

The consent to perform the study was granted by the Bioethics Commission (No. 10/2/2015). Tests were performed by qualified physiotherapists and were carried out between November 2017 and February 2018.

Participants

The study group consisted of 135 healthy, non-smoking young adults aged 18-30 years (96 women and 36 men), who signed informed consent to participate in the study. The mean age was 21.01 ± 2.22 yrs (mean age of women 20.76 ± 2.21 yrs, the mean age of men 21.64 ± 2.16 yrs).

The inclusion criteria were the age between 18 and 30 yrs, informed consent, fasting status, lack of diagnosed chronic diseases including problems with hypertension, which was verified prior to testing. Exclusion criteria were: age younger than 18 or older than 30 yrs, smoking, diagnosis of asthma, lack of informed consent, the condition of the body after eating a meal, pregnancy, pacemaker, the presence of metallic implants in the subject's body, the presence of chronic diseases.

Anthropometric measurements

Each subject had the anthropometric values (body height, waist and hip circumference to determine WHR) measured and the author used a questionnaire which included questions, among others, on demographic data (age, gender, place of residence), as well as place of residence or work in a dusty area.

Body composition

The body composition analyzer (BC-420m, Tanita) has been used to estimate body composition. The device uses foot-to-foot bioelectrical impedance analysis (BIA) method. BIA method relies on the measurement of electrical resistance, which has different values for each kind of soft tissues in the body, through which electric current of low intensity flows [10]. The study was performed on fasting participants who were informed about contraindications to perform the assessment of body composition with BIA.

Spirometry

Spirometry was performed by means of Spirolab II. Patient was in sitting position, with feet flat on the floor, loosen tight-fitting clothing and arms on the chair. Before performing the forced expiration, normal breaths was taken first, then a deep breath taken in while still using the mouthpiece, followed by a further quick, full expiration and finished the test by inspiring again as fast as possible. In order to confirm the accuracy of the sample performed by each subject, the tests were performed three times and a recorded result was the average value of the data obtained. The results of the respondents referred to the predicted values, which were determined according to ATS recommendations claiming that due to small changes in lung function in young adults between 18 and 25 yrs, it is recommended to apply the value of 25 yrs to calculate the predicted values [11].

Data analysis

The obtained data were statistically analyzed using descriptive statistics, Spearman correlation coefficient and Mann-Whitney test adopting the level of statistical significance at $p < 0.05$.

Results

The characteristics of the study group is presented in Table 1 and Table 2. In the study group, slightly more subjects lived in the village than in the city (55.6% vs. 44.4%). A significant minority of the respondents declared to live in the dusty area (28.1% vs. 71.9%). The fact of working in the dusty area was reported by 1/5 of the respondents (20.7%). The remaining 79.3% worked or studied in a dust-free area.

Slightly more than a half of the subjects declared that they regularly undertake physical activity (51.9%) (Table 1).

Table 1. Characteristics of the study group

	Number	%
Place of residence		
City	60	44,4
Village	75	55,6
Living in a dusty area		
No	97	71,9
Yes	38	28,1
Work / study in a dusty area		
No	107	79,3
Yes	28	20,7
Regular physical activity		
No	65	47,4
Yes	70	51,9

Average value of BMI in study group is 21,9 ± 3,39 (median 21,7). Average BFP was significantly higher in women compared to men (22.8 vs. 13.7, $p \leq 0.001$). The opposite situation regarded lean tissue and visceral adipose tissue. In men, the mean Visceral Fat Rating amounted to 2.4 and 1.4 in women ($p = 0.006$). The average content of the lean tissue in males was 67.5 kg and 44.7 kg in females ($p \leq 0.001$) (Table 2).

Table 2. Characteristics of the study groups within the parameters of body composition

Sex	BFP					
	N	$\bar{x}$	Me	*s*	c_{25}	c_{75}
Female	96	22,8	23,2	7,4	18,1	27,9
Male	39	13,7	13,6	5,0	9,0	17,2
P	≤ 0.001					
	VISCERAL FAT RATING					
	N	$\bar{x}$	Me	*s*	c_{25}	c_{75}
Female	96	1,4	1	1,0	1	2
Male	39	2,4	2	2,2	1	3
P	0.006					
	FFM					
	N	$\bar{x}$	Me	*s*	c_{25}	c_{75}
Female	96	44,7	44,8	3,3	42,0	46,9
Male	39	67,5	68,8	9,5	59,8	72,7
P	≤ 0.001					

BFP – body fat percentage FFM – free – fat mass

The results of various respiratory parameters in the study group were analyzed separately in males and females, and presented as % of the desired value in Table 3. There were no statistically significant differences between the results of spirometry among men and women. The only difference approaching the level of statistical significance is the parameter FIVC, its measurements were closer to the norm for men (average of 78.7% of norm vs. 72.6% of norm in women).

The influence of the characteristics associated with the body composition to the spirometric parameters were considered separately in the group of men and women, as sex differentiates significantly values of body composition. The value of the correlation coefficient was presented and the results which were statistically significant ($p < 0.05$) were marked with an asterisk (*).

Table 3. The values of respiratory parameters in the study group

	Sex								p
	Female				Male				
	N	$\bar{x}$	Me	s	N	$\bar{x}$	Me	s	
FVC (L)	96	84,0	85,6	13,8	39	87,1	84,7	21,8	0,428
FEV1 (L)	96	85,0	85,1	16,1	39	80,5	84,4	23,4	0,458
FEV1 % (%)	96	105,0	107,6	14,2	39	98,6	110,6	26,0	0,860
PEF (L/s)	96	63,6	63,8	23,9	39	61,5	62,0	26,7	0,616
FEF 25/75 (L/s)	96	87,4	85,8	29,8	39	91,7	93,5	38,2	0,518
FEF 25% (L/s)	96	67,6	68,1	25,8	39	63,9	64,8	29,8	0,475
FEF 50% (L/s)	96	77,5	77,0	27,0	39	81,4	80,1	34,5	0,521
FEF 75% (L/s)	96	103,1	100,0	37,1	39	118,9	114,2	53,8	0,137
FIVC (L)	96	72,6	74,5	17,1	39	78,7	79,3	16,3	0,094
FIV1%	96	89,7	92,2	24,5	39	87,3	98,9	35,8	0,431
PIF (L/s)	96	29,4	25,2	13,9	39	31,5	31,4	16,8	0,527

FEF 25% – maximum flow at 25% of FVC; FEF 50% – maximum flow at 50% of FVC; FEF 75% – maximum flow at 75% of FVC; FEF 25/75 – average flow from 25% to 75% of FVC; FEV1 – forced expiratory volume in one second; FIV1%: FIV1/FIVCx100; FIVC – forced inspiratory vital capacity; FVC – forced vital capacity; PEF – peak expiratory flow; PIF – peak inspiratory flow.

Statistically significant relationship between FVC and several indicators of body composition such as body weight, BFP, visceral adipose tissue (Visceral Fat Rating) and BMI were found in the group of women.

Women with a higher body weight and body fat obtained better FVC parameter (they are closer to norm). It is proved by the correlation coefficient at the level of 0,21-0,24. These results were statistically significant (Table 4).

Single statistically significant correlations regarding FEV1%, and body mass (correlation coefficient – 0.23) as well as FIVC and WHR (correlation coefficient 0.24) were also found. In the case of the first dependency, lower body mass determines a better FEV1% parameter and the situation is reversed in case of the other dependency – higher WHR values condition better forced inspiratory vital capacity (FIVC) (Table 4).

Table 4. Dependence of respiratory parameters and indicators of body composition in women

Respiratory parameters (% of the required)	Indicators of female body compositions						
	Body mass	Body height	BFP	Free -fat mass (kg)	Visceral Fat Rating	Wa-ist-to -hip ratio	BMI
FVC (L)	**0,21***	0,07	**0,22***	0,15	**0,21***	0,16	**0,24***
FEV1 (L)	0,03	-0,08	0,10	0,00	0,12	0,02	0,12
FEV1%	**-0,23***	-0,18	-0,18	-0,18	-0,13	-0,19	-0,16
PEF (L/s)	-0,10	-0,17	-0,05	-0,10	0,01	0,03	-0,01
FEF 2575 (L/s)	-0,09	-0,08	-0,04	-0,06	0,00	-0,04	-0,05
FEF 25% (L/s)	-0,09	-0,16	-0,03	-0,11	-0,01	0,01	-0,01
FEF 50% (L/s)	-0,06	-0,09	-0,01	-0,06	0,03	0,00	-0,01
FEF 75% (L/s)	-0,15	-0,14	-0,10	-0,14	-0,08	-0,10	-0,09
FIVC (L)	0,09	-0,02	0,16	0,01	0,18	**0,24***	0,16
FIV1%	0,09	0,04	0,16	0,01	0,17	0,03	0,13
PIF (L/s)	-0,01	-0,10	0,06	-0,09	0,06	0,14	0,03

BFP: body fat percentage; BMI: body mass index; FEF 25% – maximum flow at 25% of FVC; FEF 50% – maximum flow at 50% of FVC; FEF 75% – maximum flow at 75% of FVC; FEF 25/75 – average flow from 25% to 75% of FVC; FEV1 – forced expiratory volume in one second; FIV1%: FIV1/FIVCx100; FIVC – Forced inspiratory vital capacity; FVC – forced vital capacity; PEF – peak expiratory flow; PIF – peak inspiratory flow.

More strong correlation of normalized respiratory parameters of body weight, FFM or BMI were found in the population of males, but most of them were statistically insignificant, which may result from the fact that the group of men was less numerous than the group of women. The only statistically significant correlations concern FIV1% and WHR – the bigger WHR, the closer FIV1% value to normal (Table 5).

Table 5. Dependence of respiratory parameters and body composition indicators in men

Respiratory parameters (% of the required)	Indicators of male body compositions						
	Body mass	Body height	BFP	Free-fat mass (kg)	Visceral Fat Rating	Waist-to-hip ratio	BMI
FVC (L)	0,27	0,14	0,19	0,24	0,11	0,27	0,23
FEV1 (L)	0,16	-0,02	-0,01	0,17	0,01	-0,06	0,11
FEV1%	-0,04	-0,15	-0,14	0,01	-0,12	-0,13	-0,02
PEF (L/s)	0,19	-0,18	0,11	0,18	0,12	-0,07	0,25
FEF 2575 (L/s)	0,25	0,00	0,07	0,28	0,08	0,08	0,24
FEF 25% (L/s)	0,24	-0,08	0,12	0,25	0,10	0,00	0,28
FEF 50% (L/s)	0,21	-0,05	0,06	0,25	0,07	0,07	0,24
FEF 75% (L/s)	0,06	0,02	-0,06	0,09	-0,07	0,13	0,02
FIVC (L)	0,18	0,13	0,21	0,17	0,12	**0,38***	0,15
FIV1%	-0,07	-0,24	0,15	-0,12	0,14	0,10	0,07
PIF (L/s)	0,27	0,15	0,20	0,26	0,15	0,08	0,32

BFP: body fat percentage; BMI: body mass index; FEF 25% – maximum flow at 25% of FVC; FEF 50% – maximum flow at 50% of FVC; FEF 75% – maximum flow at 75% of FVC; FEF 25/75 – average flow from 25% to 75% of FVC; FEV1 – forced expiratory volume in one second; FIV1%: FIV1/FIVCx100; FIVC – Forced inspiratory vital capacity; FVC – forced vital capacity; PEF – peak expiratory flow; PIF – peak inspiratory flow.

Discussion

Numerous authors from around the world including Spathopoulos et al. confirmed that increased BMI at the developmental age should be considered as an important determinant for decrease in spirometric values [12].

Costa Junior D et al. investigated the respiratory system in 75 children, including 35 obese and 40 normal weight individuals. As in our study, adopted indicators of lung function were compared with the results of anthropometric measurements and body mass indices. The authors confirmed in their study the presence of significant correlations between these parameters and excessive body mass may predispose to reduction of volume and lung function (lower FEV1%). Negative impact on the strength of respiratory muscles was not proved [13]. Our study leads to a similar conclusion, where young women scored better vital capacity of the lungs marked with Tiffenau indicator with a body mass close to normal. An inverse relationship was confirmed in a group of both young women and men in WHR correlation and FIVC%. Negative correlation between FEV1 and WHR index was also obtained by Kayode Oke et al. in study on the effect of body composition on respiratory function in Nigerian amateur boxers. This result is consistent with our results [14].

Extensive data provided prospective cohort study conducted by Paul Duarte de Oliveira et al., in a group of 1,964 boys and 1,945 girls. The results of the analysis as in our study showed that all indicators of fat mass (FM) had a significant effect on reducing the rates of respiratory function, primarily FVC. The opposite trend was observed in the case of fat-free components, the growth of which was associated with improvement in spirometric results [15]. This assumption was not confirmed in this study, which showed no statistically significant correlation between respiratory parameters and fat-free components and visceral adipose tissue in most studies. Shah et al. in the studies over a group of 186 young adults aged 17-21 years also found that FM and FFM were correlated significantly with dynamic lung function in young people. In females, FM was associated with reduced lung function. In men, BMI and FFM were correlated positively with pulmonary function [16].

The presence of fat in internal organs and its strong influence on respiratory complications in obese patients have been extensively described by Busetto et al. and Ferreira, et al. [17,18]. The present findings show that significant impact of visceral body fat have been observed in the study group only among women, and only in relation to the value of FVC. Lack of this correlation in men could be explained by lower number of subjects in this group in our study. Similarly to the present results, the study by Choe et al. reported that decreasing visceral adipose tissue were related to increasing FEV1 and FVC in both males and females [19].

The results obtained did not confirm any significant correlation between BMI, BFP and all indicators of respiratory function, except FVC only in women. Similar conclusions were drawn by Jung Eun Park et al., who analyzed the results of a group of 291 adults and found no correlation in the group of men [20]. It is believed that a greater correlation between the other indicators could be confirmed by the studies in which the test group included more people with excess weight, or obesity. Such studies were conducted by Umesh Pralhadrao Lad et al. The study group comprised of young people similar to our study, however, they were categorized into three different BMI groups (underweight, normal weight, overweight). It was found that the mean FVC and FEV1 were lower in the group with underweight or overweight, and these correlations were statistically significant [21].

The obtained results confirmed significant correlations between selected parameters of respiratory function and components of body mass of young people. Thus the analysis of anthropometric parameters and components of body mass is extremely important and should be carried out not only among young people and adults, but right from early childhood. Particular attention is required in children and young people with abnormal body mass or obesity, which increase the risk of dangerous chronic diseases in adulthood, including respiratory disorders [22].

The analysis of body composition is increasingly important in children and young people with existing pulmonary conditions i.e. bronchial asthma or cystic fibrosis. According to Raquel Granell et al., the relationship between the ratio of body fat and lean body and the development of asthma is so high that they suspect that the growing problem of obesity among children and youth worldwide can contribute to the rising incidence of asthma, observed in the late twentieth century [23]. Barros et al. argue that obesity increases the odds of a more persistent and severe asthma phenotype independently of physical activity and eating habbits [24].

Haren et al. in their study found that women with higher intra-abdominal fat had more severe asthma symptoms, which did not correlate with lower FEV1. In men, higher IAF value was significantly associated with reduced FEV1 and FVC and breathing disorders during sleep [25]. Similar results were obtained by Scott et al. who described adverse effects of excessive body fat on respiratory functions in obese asthmatics [26].

Fenger et al. studied for five years long-term changes in weight, body mass index (BMI), waist circumference, and body fat with long-term changes in FEV1 and FVC at 2,294 individuals with concomitant asthma and wheezing. The studies showed that an increase in body fat was associated with a reduction in lung function, while reducing body fat was associated with improved lung function. This effect was significantly greater in men than in women [27]. The opposite stand represents Al Ghobain. His studies showed that obesity does not affect the results of spirometry (with the exception of PEF) in healthy non-smoking adults. The author also recommends searching for an alternative diagnosis in the case of abnormal spirometry test results among obese patients [28].

There are numerous studies in the available literature describing the effect on body composition on respiratory functions in patients with Chronic Obstructive Pulmonary Disease (COPD). Dias et al. confirmed that deteriorated respiratory function in patients with COPD is associated with changes in the composition of body mass [29]. Similar results were obtained by Eisner et al. Body composition is an important non-pulmonary factor modulating the risk of functional limitation in COPD. Abnormalities of body composition may represent an important area of screening and preventive intervention in COPD [30].

In conclusion, determination of selected components of the body mass is here adjuvant factor, which could help in the treatment of respiratory rates and maintaining the best possible level. Repeated bioimpedance research allows to determine improvement in the body mass parameters and should be treated as a complementary method. Our data confirm that women with a higher body mass and body fat obtained better FVC parameters while lower FEV1%. Higher WHR values condition better forced inspiratory volume capacity (FIVC) in women and men. Incorrect values of body mass can be considered as a factor decreasing the parameters of respiratory function.

References:

1. WHO Obesity and overweight. Fact sheet 18 December 2017
2. Koyuncuoğlu Güngör N. Overweight and Obesity in Children and Adolescents. J Clin Res Pediatr Endocrinol 2014; 6(3):129–143. doi: 10.4274/jcrpe.1471.
3. Johnson MJ, Beattie RM. Making body composition measurement a part of routine care in children. Clin Nutr 2018;37(3):763-764. doi: 10.1016/j.clnu.2018.01.033.
4. Przybylska D, Kurowska M, Przybylski P. Obesity and overweight in the adolescent population. Hygeia Public Health 2012; 47(1):28-35.
5. Ahima RS. Digging deeper into obesity. The Journal of Clinical Investigation 2011;121(6):2076 – 2079. doi: 10.1172/JCI58719.
6. Vitezova A, Muka T, Zillikens MC. Vitamin D and body composition in the elderly. Clin Nutr 2017;36(2):585-592.
7. De Pergola G, Silvestris F. Obesity as a Major Risk Factor for Cancer. Journal of Obesity 2013; 2013:291546. doi: 10.1155/2013/291546.
8. Manuel AR, Hart N, Stradling JR. Correlates of obesity-related chronic ventilatory failure. BMJ Open Respiratory Research 2016;3(1):000110. doi: 10.1136/bmjresp-2015-000110
9. Wannamethee SG, Shaper AG, Whincup PH. Body fat distribution, body composition, and respiratory function in elderly men. The American Journal of Clinical Nutrition 2005;82(5):996-1003.
10. Dżygadło B, Łepecka-Klusek C, Pilewski B. Use of bioelectrical impedance analysis in prevention and treatment of overweight and obesity. Problems of Hygiene and Epidemiology 2012;93(2):274-280.
11. Perillo M. Spirolab II. User's manual. 2001:24.
12. Spathopoulos D, Paraskakis E, Trypsianis G et al. The effect of obesity on pulmonary lung function of school aged children in Greece. Pediatric Pulmonology 2009;44(3):273–280.
13. Costa Junior D, Peixoto-Souza FS, Araujo PN et al. Influence of Body Composition on Lung Function and Respiratory Muscle Strength in Children With Obesity. Journal of Clinical Medicine Research 2016;8(2):105-110. doi: 10.14740/jocmr2382w.

14. Oke Kayode I, Agwubike Elias O. Body composition and pulmonary functional correlates in Nigerian male amateur boxers. Medicina Sportiva 2015; 11(2):2563-2568.

15. Duarte de Oliveira P, Baptista Menezes AM, Wehrmeister FC et al. Body composition and pulmonary function at 18 years old: Findings from a birth cohort in southern Brazil. European Respiratory Journal 2015; 46(59):PA1105. doi: 10.1371/journal.pone.0163428.

16. Shah HD, Patel NH, Patel D et al. Effect of gender and body composition on dynamic lung function tests in young Gujarati Indian population. International Journal of Medical Science and Public Health 2015; 4(11):1594-1597.

17. Busetto L, Sergi G. Visceral fat and respiratory complications. Diabetes, Obesity and Metabolism 2005; 7(4):301–306.

18. Ferreira MS, Mendes RT, de Lima Marson FA et al. The relationship between physical functional capacity and lung function in obese children and adolescents. BMC Pulmonary Medicine 2014; 14(199). doi: 10.1186/1471-2466-14-199.

19. Choe EK, Kang HY, Lee Y, Choi SH, Kim HJ, Kim JS. The longitudinal association between changes in lung function and changes in abdominal visceral obesity in Korean non-smokers. PLoS One 2018; 23(13):e0193516, 2018.

20. Kongkiattikul L, Sritippayawan S, Chomtho S et al. Relationship between Obesity Indices and Pulmonary Function Parameters in Obese Thai Children and Adolescents. Indian Journal of Pediatrics 2015; 82(12):1112-1116. doi: 10.1007/s12098-015-1777-4.

21. Lad UP, Jaltade VG, ShiSode-lad S et al. Correlation Between Body Mass Index (BMI), Body Fat Percentage and Pulmonary Functions in Underweight, Overweight and Normal Weight Adolescents. Journal of Clinical and Diagnostic Research 2012; 6(3):350-353.

22. Alvarez JA, Ziegler TR, Millson EC et al. Body composition and lung function in cystic fibrosis and their association with adiposity and normal-weight obesity. Nutrition 2016;32(4):447-52. doi: 10.1016/j.nut.2015.10.012.

23. Granell R, Henderson AJ, Evans DM et al. Effects of BMI, fat mass, and lean mass on asthma in childhood: a Mendelian randomization study. PLoS Med 2014;11(7):e1001669, 2014.

24. Barros R, Moreira P, Padrão P, Teixeira VH, Carvalho P, Delgado L, Moreira A. Obesity increases the prevalence and the incidence of asthma and worsens asthma severity. Clinical Nutrition 2017; 36(4):1068-1074.

25. Haren MT, Misan G, Paterson TJ et al. Abdominal adiposity and obstructive airway disease: testing insulin resistance and sleep disordered breathing

mechanisms. BMC Pulmonary Medicine 2012; 12(31). doi: 10.1186/1471-2466-12-31. doi: 10.1186/1471-2466-12-31.

26. Scott HA, Gibson PG, Garg ML et al. Relationship between body composition, inflammation and lung function in overweight and obese asthma. Respiratory Research 2012;13(10):2012. doi: 10.1186/1465-9921-13-10.
27. Fenger RV, Gonzalez-Quintela A, Vidal C et al. The longitudinal relationship of changes of adiposity to changes in pulmonary function and risk of asthma in a general adult population. BMC Pulmonary Medicine 2014; 22;14:208. doi: 10.1186/1471-2466-14-208.
28. Al Ghobain M. The effect of obesity on spirometry tests among healthy non-smoking adults. BMC Pulmonary Medicine 2012; 12(10):2012. doi: 10.1186/1471-2466-12-10.
29. Dias FD, Gomes ELFD, Stirbulov R et al. Assessment of body composition, functional capacity and pulmonary function in patients with Chronic Obstructive Pulmonary Disease. Fisioterapia e Pesquisa 2014; 21(1):10-15.
30. Eisner MD, Blanc PD, Sidney S et al. Body composition and functional limitation in COPD. Respiratory Research 2007; 8(7):2007. doi:10.1186/1465-9921-8-7.