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Original Article

Correlation Between Body Mass Index (BMI), Body Fat Percentage and Pulmonary Functions in Underweight, Overweight and Normal Weight Adolescents

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ABSTRACT

Introduction: In India, undernutrition coexists with obesity, thus demonstrating a “double burden of the disease.” The effect of the increased BMI and the body fat percentage on the pulmonary functions has been studied extensively. The effect of undernutrition and mild weight gain on the pulmonary functions needs attention.

Objectives: The aim of this study was to investigate whether there was any correlation between the Body Mass Index, Body Fat Percentage and FVC, FEV_1 and FEF_{25-75}, in underweight, normal weight and overweight adolescents.

Materials and Methods: 180 students who consisted of 90 boys and 90 girls in the age group of 18 to 21 years, who were in three BMI ranges were enrolled. They were classified into underweight, normal weight and overweight groups according to the WHO guidelines. The body fat percentage was measured by using the bioelectric impedance method and FVC, $FEV_1$and FEF_{25-75} were assessed by using MIR-SPIROLAB-II as per the ATS guidelines.

Results: The mean values of FVC and FEV_1 were less in the underweight and overweight subjects and the difference was significant across the BMI ranges. The FEF_{25-75} values were low in the overweight than in the normal weight subjects. FVC, $FEV_1$and FEF_{25-75} had a negative correlation with BMI and the body fat Percentage in males. The underweight males had a positive significant correlation between BMI, body fat percentage and FVC, $FEV_1$and FEF_{25-75}. In females, only FEF_{25-75} had a significant correlation with BMI and the body fat percentage.

Conclusion: There was a significant difference in the FVC, FEV_1 and the FEF25-75 values between the underweight, normal weight and the overweight subjects. BMI as well as the body fat percentage had a significant negative correlation with FVC and FEV_1 in the overweight group. A significant positive correlation was observed between BMI, body fat percentage and FCV and FEV_1. Body fat percentage had a stronger correlation than BMI. FEF_{25-75} had a strong negative correlation with the body fat percentage only in the overweight group.

Key Words: BMI, Body Fat percentage, FVC, FEV_1 and FEF_{25-75}

INTRODUCTION

Indo-Asian countries are now experiencing the unique challenge of a rapid rise in childhood obesity despite a persistently high burden of undernutrition [1]. Undernutrition coexists with obesity, thus demonstrating a “double burden of the disease” [2]. While the clinical complications of obesity such as diabetes, vascular disease, and osteoarthritis are well established, less emphasis is traditionally placed on the effects of obesity on the respiratory system [3]. Obese and overweight people are at an increased risk of respiratory symptoms, such as breathlessness, particularly during exercise, even if they have no obvious respiratory illness. The association between obesity and asthma has also raised new concerns about whether the mechanical effects of obesity on the respiratory system contribute to airway dysfunction that could induce or worsen asthma [4].

Various studies have been done, which have shown the effect of severe and morbid obesity on the pulmonary functions [5,6,7,8]. Very few studies have been focused on the effect of moderate weight gain on the pulmonary functions [8,9]. The studies which have been done on the pulmonary functions in the undernourished population without any comorbidity are very few and there is a need to address this issue to understand the correlation between BMI [Body Mass Index] and the pulmonary functions.

In the present study, we tried to investigate whether there was any correlation between BMI and the pulmonary functions in three ranges of BMI viz underweight, normal weight and overweight. In addition to this, we tried to check whether there was any correlation between the body fat percentages and the pulmonary functions in these three groups by doing a separate correlation.

MATERIALS AND METHODS

In this study, 180 subjects who consisted of 90 boys and 90 girls were enrolled from our institute. The study protocol was ethically approved by the institutional ethical committee and the informed consent of the volunteers was taken.

Experimental Protocol

This study was conducted on the first year and second year M.B.B.S. students from the institute during a three year period. The ages of the subjects were recorded from their date of birth in their school leaving certificates. All the participants were selected on the basis of inclusion and exclusion criteria. Students with cardiovascular and respiratory disorders, those who were on active treatment for respiratory tract infections, those who were involved in active muscle training exercises and those who had a history of hypertension, diabetes and congenital anomalies were excluded from the study [6,10]. Students between the ages of 18-21 years, with a BMI of below 30, with no history of smoking and alcoholism were included in the study.

Measurement of the Anthropometric Parameters

The standing height of the subjects was measured with the same stadiometer, without footwear; to the nearest centimetre. Weight was measured, which was the nearest to 0.1 kg, with the subjects in the standing position, before lunch, with light clothes and without footwear, by using a standardized weighing scale [11]. Body mass index [BMI] was calculated by using Quetlet's index [body weight in kg/height in m^2] [12]. Depending on their BMI values, the subjects were classified into three groups. The subjects with a BMI value of less than 18.5 were classified as underweight, subjects with a BMI value between 18.5 to 24.99 [Kg/M^2] were classified as the normal weight group and those who had a BMI value between 25 to 29.99 [Kg/M^2] were classified as overweight [13]. There were 30 boys and 30 girls in each group.

Measurement of the Body Fat Percentage

Body fat percentage was measured by the bioelectric impedance method by using an Omron hand held bioelectric impedance analyzer which measures the hand to hand impedance. The height, weight and age of the subjects were entered in the instrument, they were asked to hold the instrument in both hands and after that, the digital reading of the body fat percentage was recorded.

Measurement of the Pulmonary Functions

The pulmonary functions were measured by using a computerized portable spirometer MIR [Medical International Research] SPIROLAB II as per the ATS/ERS [American Thoracic Society/ European respiratory Society] guidelines. The volunteers were asked to avoid beverages like tea, coffee and other stimulants and to report on a light breakfast. The pulmonary functions were recorded in the forenoon to avoid the diurnal variations. The subjects were demonstrated the FVC [Forced Vital Capacity] maneouver in spirometry.. After they were allowed to rest for 5–10 min and after educating them about the technique of FVC [maximum inhalation followed by maximum exhalation and this had to be sustained until they were asked to inhale again], the test was carried out in a private and quiet room, with the subjects in a standing position, with the nose clip held in position on the nose. The flow volume/ time graphs were taken and best of the three acceptable curves was selected as the recording. The values of FVC [Forced Vital Capacity], FEV_1 [Forced Expiratory Volume in the first second] and FEF_{25-75} [Forced Expiratory Flow in 25-75% /Mid expiratory flow] were taken for the statistical analysis. The instrument was calibrated daily by using a 2 litre syringe [14].

STATISTICAL METHODS

The data were expressed in mean±SD and they were analyzed by using the SPSS version 10 [Statistical Package for Social Sciences] statistical software, ANOVA correlations and the Z test. ANOVA was applied for the three groups of BMI in the entire study. FVC, FEV_1 and FEF_{25-75} were correlated with BMI and the body Fat Percentage. The significance level was set at p values which were < 0.05 and it was considered as significant.

RESULTS

BMI and body fat percentage were significantly different in the underweight, normal weight and the overweight subjects, [$p < 0.0001$] (Table/Fig-1). There was a significant difference between the FVC, FEV_1 and FVF_{25-75} values across the three groups in both males and females [Table/Fig-2].

In the underweight males, there was a positive correlation between body fat percentage and the FVC, FEV_1 and FEF_{25-75} values. In the normal weight males, there was a negative correlation between BMI and FEV_1 as well as between BMI and FEF_{25-75}. In the overweight males, BMI as well as the body fat percentage showed a significant negative correlation with the FVC, FEV_1 and the FEF_{25-75} values [Table/Fig-3]. In underweight females, BMI and the body fat percentage showed a significant positive correlation with FVC and FEV_1. The normal weight females showed a significant positive correlation between BMI and FVC and FEF_{25-75} and between body fat percentage and FEF_{25-75}. In overweight females, the correlation between BMI and FVC was positive, while the correlation between the body fat percentage and FEF_{25-75} was negative [Table/Fig-4].

DISCUSSION

In this population based cross-sectional study, we investigated the correlation of the body mass index [BMI] and the body fat percentage with FVC, FEV_1 and FEF_{25-75}, based on the hypothesis that not only an increase in the BMI but also a decrease in the BMI in the underweight population will lead to a decrement in the pulmonary functions. A reduction in the pulmonary functions might be associated with the body fat percentage rather than the BMI in the overweight population and with lack of energy in the underweight population. In this study, we made an attempt to find out whether there was an increased risk of asthma in the overweight population, as was determined by the mid-air flow rate which was assessed by FEF_{25-75}.

Group	BMI(Kg/M^2)			F-Value	P-Value
	Underweight	Normal weight	Overweight		
	Mean±SD	Mean±SD	Mean±SD		
Male	16.82±1.05(n=30)	21.49±1.39(n=30)	27.56±1.22(n=30)	573.96	<0.0001
Female	17.15±0.17(n=30)	20.90±1.35(n=30)	27.13±1.59(n=30)	496.68	<0.0001
Total	16.98±0.91(n=60)	21.20±1.39(n=60)	27.34±1.43(n=60)	1020.08	<0.0001
Body fat percentage(%)					
Male	12.15±1.91(n=30)	14.40± 1.45(n=30)	21.23± 1.79(n=30)	225	<0.0001
Female	21.1± 0.89(n=30)	25.24± 1.16(n=30)	31.21± 2.57(n=30)	232.62	<0.0001
Total	16.63± 4.78(n=60)	19.82± 5.67(n=60)	26.22± 5.49(n=60)	50.67	<0.0001

[Table/Fig-1]: Shows comparison of BMI and Body fat percentage in three groups.
p value <0.05 is taken as significant.

Group	FVC(L)			F-value	P value
	Under-weight	Normal weight	Overweight		
	mean±SD	mean±SD	mean±SD		
Male	3.47±0.44	3.73±0.79	3.34±0.90	2.16	>0.05
Female	2.52±0.31	2.94±0.48	2.60±0.33	10.27	<0.0001
Total	2.99±0.61	3.34±0.76	2.97±0.77	4.85	<0.01
FEV_1(L/sec)					
Male	3.21±0.41	3.29±0.76	2.87±0.76	3.49	<0.05
Female	2.44±0.35	2.64±0.39	2.22±0.22	11.83	<0.0001
Total	2.82±0.54	2.96±0.68	2.54±0.76	7.01	<0.05
FEF_{25-75}(L/sec)					
Male	4.10±0.99	4.12±1.24	3.48±1.09	3.18	<0.05
Female	4.13±0.84	3.50±0.96	2.51±0.35	34.66	<0.0001
Total	4.12±0.91	3.81±1.14	2.99±0.94	20.11	<0.0001

[Table/Fig 2]: Showa FVC,FE1 and FF25-75 in three groups
p value <0.05 is taken as significant.

Correlation between	'r' Value		
	Underweight	Normal weight	Overweight
BMI and FVC	0.03	-0.19	-0.59**
BMI and FEV_1	0.001	-0.36*	-0.58**
BMI and FEF_{25-75}	0.36*	-0.44*	-0.39*
Body fat % and FVC	0.29*	0.08	-0.64**
Body fat % and FEV_1	0.33**	-0.03	-0.63**
Body fat % and FEF_{25-75}	0.47**	-0.13	-0.48**

[Table/Fig-3]: Shows Correlation between BMI, Body Fat percentage and FVC, VE1and FF25-75

There was a statistically significant reduction in the FVC and FEV_1 values in the males and females of the three groups, with the least mean±SD values in the overweight population than in the underweight and the normal weight populations. The underweight males as well as females had lesser mean values of FVC and FEV_1 as compared to those of their normal weight counterparts; thus suggesting that there was a decrease in the FVC and FEV_1 values in the underweight and overweight populations.

BMI and FVC showed a significant negative correlation in the overweight males and females and the correlation was stronger in males than in females. The overweight males showed a significant negative correlation between body fat percentage and FVC. The overweight females showed no correlation, thus suggesting that the body fat had decreased the FVC values only in males and not in females of the overweight group. FEV_1 showed a significant negative correlation with BMI and body fat percentage in the overweight males. The females of the overweight group showed no correlation between FEV_1 and BMI. A non-significant negative correlation was found between FEV1 and body fat percentage. This also showed that the decrement of the pulmonary functions was more in males than in females due to their body fat distribution.

Our results were similar to the results of Farida M. El-Baz et al [15] and Wannamethee et al. [7] They found that BMI was inversely correlated with most of pulmonary function abnormalities. Low FVC, FEV_1 values indicated a restrictive pulmonary defect. This could have been due to the mechanical limitation of the chest expansion, as the accumulation of excess fat could interfere with the movement of the chest wall and the descent of the diaphragm. This may reflect intrinsic changes within the lung in the presence of

Correlation between	'r' Value		
	Underweight	Normal weight	Overweight
BMI and FVC	0.34*	0.27*	0.27*
BMI and FEV_1	0.37*	-0.14	0.18
BMI and FEF_{25-75}	0.16	0.28*	-0.24
Body fat % and FVC	0.29*	-0.01	-0.23
Body fat % and FEV_1	0.29*	0.11	0.12
Body fat % and FEF_{25-75}	0.18	0.33*	-0.29*

[Table/Fig-4]: Correlation between BMI and Body fat percentage with FVC, FEV1 and FEF25-75 in females of three groups.

obesity [15,8]. In addition, high amounts of fat mass and adiposity may be related to a greater degree of airway narrowing [7]. The results of the present study matched with those of Joshi *et al's* [10] and Collins et al's [11] studies, who found that the increased body fat % in the males and females showed a negative correlation with FVC. The negative correlation of the increased percentage of body fat and FEV_1 was observed only in males, as had been reported earlier [5, 16]. The results of this study disagreed with those of Muralidhara's and Bhat's studies, who found no correlation between BMI, body fat percentage and the pulmonary functions [17].

The visceral adipose tissue influences the circulating concentrations of cytokines such as interleukin-6 and TNF-alpha [18 ,19]. A decreased level of adiponectin thereby increases the levels of systemic inflammation, which might in turn negatively affect the pulmonary functions [9] The airway calibre of the obese persons is reduced, for which the exact cause remains unknown, but the possible mechanism could be remodeling of the airway by pro-inflammatory adipokines and/or by the continuous opening and closing of small airways throughout the breathing cycle [20].

In our study, we found that males had a more significant loss of the pulmonary functions than females and that the negative correlation between BMI, body fat percentage and pulmonary functions was stronger in males than in females. This association might be due to differences in the adiposity pattern of males and females. Males have a central obesity, while females have peripheral obesity. In central obesity, there is more visceral fat deposition; the visceral fat being metabolically more active than the peripheral fat, it will lead to more loss of pulmonary functions in addition to the mechanical restrictions [10,11].

In the underweight population, the body fat and BMI showed a significant positive correlation with FVC and FEV_1 in males as well as in females, thus stating that an improvement in the nutritional status of the underweight group could help in improving the pulmonary functions of the underweight population. Malnutrition unfavourably influences the lung functions by decreasing the respiratory muscle mass, strength, endurance and the defense mechanisms of the lung immune system. Muscle wasting leads to reduction in the diaphragmatic mass and a weaker respiratory muscle function diminishes the respiratory muscle strength and it changes the ventilator capacity [16]. According to Fernando Sempertgui, vitamin A can be a link between the direct correlation between FEV1 and FVC in malnourished children [21].

In our study, no participant was a diagnosed asthmatic. FEF_{25-75} is an indicator of the mid expiratory flow rate and so, it was taken as a marker for obstructive lung diseases like asthma and COPD. We found a significant difference across the three BMI ranges, with the lowest mean values in overweight males and females;

thus suggesting that they were prone to develop obstructive lung disease. Our results did not agree with the results of Wen Cho Ho et al. They found an inverse correlation between BMI and the pulmonary functions in females [22]. We found a strong significant negative correlation in males and a non significant negative correlation in females. Our results agreed with those of El Helaly *et al's* studies.. They also found an inverse correlation between BMI and $FEF_{25-75.}$ They further recommended that weight reduction would lead to a better asthma control [23].

The limitation of the present study was in its design. This was a cross-sectional study which was carried out in a small group in a single institute. A longitudinal multi-centric study in a larger population is needed. We measured the fat percentage by the bioelectric impedance method which measured the total body fat but it failed to measure the distribution of the fat. A better method which could measure both the total body fat and the distribution of the body fat could have been more appropriate and it could help in a clear understanding of the association.

CONCLUSION

BMI and body fat percentage were negatively correlated with FVC and FEV_1 in males and females of the overweight group. The underweight group showed a positive correlation with FVC and FEV_1. The body fat percentage had a stronger correlation than BMI, thus suggesting that body fat percentage was a major determinant of the reduced pulmonary functions in overweight and obesity than in BMI. FEF_{25-75} had a strong negative correlation with the body fat percentage only in the overweight group. Our findings suggest that there is significant impairment of the pulmonary functions in the overweight and underweight populations and that the possibility of small airway disease is higher in the overweight group.

BIBLIOGRAPHY

[1] Jafar TH, Qadri Z, Islam M, Hatcher J, Bhutta ZA, Chaturvedi N. Rise in childhood obesity with persistently high rates of under nutrition among urban school aged Indo-Asian children. *Arch Dis Child.* 2008; 93:373–78.

[2] Marianne AB. van der Sande, Ceesay SM, Paul JM, Ousman A, Nyan et al. Obesity and undernutrition and cardiovascular risk factors in rural and urban Gambian communities. *Am J Public Health*. 2001; 91:1641–44.

[3] Salome CM, King GG, Berend N. The physiology of obesity and its effects on the lung functions. *J Appl Physiol.* 2010; 108:206–11.

[4] Piper AJ, Grunstein RR. Big Breathing: the complex interaction of obesity, hypoventilation, weight loss, and respiratory functions. *J Appl Physiol*. 2010; 108:199–205.

[5] Saxena Y, Sidhwani G, Upmanyu R. Abdominal obesity and pulmonary functions in young Indian adults: a prospective study. *Indian J Physiol Pharmacol.* 2009; 53(4):318–26.

[6] Babb TG, Wyrick BL, Delorey DS,Chase PJ, Feng MY. Fat distribution and end expiratory lung volume in lean and obese men and women. *Chest*. 2008; 134:704–11.

[7] Wannamethee SG, Shaper AG, Whincup PH. Body fat distribution, body composition and respiratory functions in elderly men. *Am J Clin Nutr*. 2005; 82:996 –1003.

[8] Jones RL, Mary-Magdalene U. The effects of body mass index on the lung volumes. *Chest*. 2006;130:827–33.

[9] Thyagarajan1 B, Jacobs DR, Apostol GG, Smith LJ, Jensen RL, Crapo RO. Longitudinal association of the body mass index with the lung functions: The CARDIA study. *Respiratory Research*. 2008; 9:31.

[10] Joshi AR, Singh R, Joshi AR. Correlation of the pulmonary function tests with the body fat percentage in young individuals. *Indian J Physiol Pharmacol.* 2008; 52(4):383–88.

[11] Collins LC, Hoberty PD, Walker JF, Fletcher EC, Peiris AN. The effect of the body fat distribution on the pulmonary function tests. *Chest.* 1995; 107:1298-1302.

[12] Garrow JS, Webster J. Quetelet's index as a measure of fatness. *Int J Obes.* 1985;9(2): 147–53.

[13] http://www.who.int/nutrition/publications/en/childgrowth_database_overview.pdf

[14] ATS/ERS Task Force. Standardization of lung functions testing. Standardization of spirometry. *Eur Respir J.* 2005; 26:319-38.

[15] El-Baz FM, Eman AA, Amal AA, Terez BK, Fahmy A. Impact of obesity and body fat distribution on the pulmonary function in Egyptian children. *EJB*. 2009; 3:49-58.

[16] Chen Y, Rennie D, Cormier YF, Dosman J. Waist circumference is associated with the pulmonary function in normal-weight, overweight, and obese subjects. *Am J Clin Nutr*. 2007; 85:35–9.

[17] Muralidhara DV, Bhat MR. Some aspects of the pulmonary functions in underweight and overweight human subjects. *Thai Journal of Physiological Sciences*. 2007; 20:3-7.

[18] Keran PA, Ranganathan S, Li C, Wood L, Ranganathan G. Adipose tissue tumor necrosis factor and interleukin-6 expressions in human obesity and insulin resistance. *Am J Physiol Endocrinol Metab*. 2001; 280: E745–51.

[19] Staiger H, Tschritter O, Machann J. Relationship of the serum adiponectin and the leptin concentrations with the body fat distribution in humans. *Obes Res* 2003; 11:368–72.

[20] Inselman LS, Wapnir RA, Spencer H. Obesity-induced hyperplastic lung growth. *Am Rev Respir Dis*. 1987; 135: 613–16.

[21] Fernando S. Is vitamin A playing a hidden role in children's lung functions? *Int J Epidemiolgy.* 2007; 30:465-66.

[22] Ho WC, Lin YS, Caffrey JL, Lin MH, Hsu HT, Myers L. A higher body mass index may induce asthma among adolescents with pre-asthmatic symptoms: a prospective cohort study. *BMC Public Health*. 2011; 11:542.

[23] Heather M. O Balcom, Grant BJB, Muti P, Christopher T. Pulmonary functions and abdominal adiposity in the general population. *Chest.* 2006; 129;853-62.

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