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Effect of distribution of body fat on pulmonary function tests in young adults

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Abstract: *Now-a-days the magnitude of the upswing in overweight and obesity prevalence has become an important health problem in developing countries particularly in India[1]. Studies have been reported regarding the relationship between different obesity markers and PFTs, but most of these tests were conducted in males, in children or in older age group. Studies in young adults is conspicuously absent, especially in India and it is a well-known fact that it is the young adults who are suffering from the killing disease called obesity. So the purpose of this study was to evaluate the association of pulmonary functions with BMI and body fat percentage in young medical students of Eastern India who represent the young adult population and who are the future medical advisors to the society. A prospective correlational study carried among 100 healthy medical students from both the sexes of their age group of 18 to 25 years having no lung diseases who were grouped into normal, overweight and obese according to BMI and normal and overweight according to body fat%. Spirometry was done in all students. Results were analyzed by using Graph pad Prism 5, comparison was done using independent group t tests and correlation was determined by Pearson's correlation coefficient. Results showed that forced vital capacity (FVC), forced expiration in 1^{st} second (FEV_1), FEV_1/FVC and maximum voluntary ventilation (MVV) were significantly decreased with increased BMI. A significant inverse correlation of BMI was found with FVC, FEV1 and MVV, while body fat % correlates with FVC & FEV_1 in both sexes; suggesting impaired respiratory muscle functions due to excessive weight on the thorax.*

Key words: *Body fat percentage, BMI , FVC,PFT, MVV*

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I. Introduction

Obesity as per WHO is defined as the abnormal or excessive collection of fat in the body to the extent that health is impaired[2]. The consequences of industrialization and urbanization, which lead to decrease in physical activity, inappropriate intake of calorie-rich easily available junk food and automated work profile has made the environment conducive to the development of obesity. Several studies have established obesity as being associated with respiratory complications such as obstructive sleep apnoea[3] and obesity hypoventilation syndrome[4], asthma both in children and adults[5,6] and is believed to reduce lung volumes. Poor respiratory function predicts overall mortality as well as death due to pulmonary diseases[7,8], cardio vascular diseases[9], and stroke[10] .

Large amount of abdominal fat mass may impede descent of the diaphragm during inspiration. A thorax with a large amount of subcutaneous fat over the chest may lead to a change in the balance between the elastic recoil of chest wall and lung-chest wall compliance[11]. Increase in body weight in the initial stages may increase lung functions due to an effect of muscularity and later increase in body weight would reduce the lung functions due to an obesity effect[12].

Several studies have examined mainly the association between body mass index (BMI) or weight change and PFTs and the associations vary in different subpopulations[11,13] . As the BMI formula depends only upon weight and height, its assumptions about the distribution between lean mass and adipose tissue are not always exact[14]. Another limitation is that BMI is a measure of generalized obesity and it does not take into account the pattern of fat distribution or body composition and in the past few years, it was suggested that the percentage of fat distribution may have distinct effects on pulmonary functions[15,16].Earlier studies have reported the relationship between the lung functions and body weight, height and body mass index [17,18,19] , but they may not be considered to be an ideal index of obesity in prediction of pulmonary dysfunction as they are indicators of body size and not body fat.

A person's total body fat percentage is the total weight of the person's fat divided by the person's weight. The resulting number reflects both essential fat and storage fat. A number of online tools are available for calculating estimated body fat percentage. Arguably, body fat percentage is the superior gauge of an individual's fitness level, as it is the only body measurement which directly calculates the particular individual's body composition without regard to the individual's height or weight[20].

The influence of increased percentage of body fat (body fat >35%) and central obesity on blood pressure and glucose intolerance has been well documented[21,22] . But not much data is available in the literature regarding the association of body fat percentage and pattern of fat distribution with PFTs.

So this study was taken up to evaluate the relation of pulmonary functions with percentage of body fat using different anthropometric measurements in young adults and also to make a comparative study between the correlation of the body fat % along with BMI as obesity indices with altered PFTs if any .

II. Materials and Methods

2.1 Sample size : A prospective correlational study was carried out among 100 healthy young adults of both sexes aged between 18 -25 years, chosen randomly from 1st year MBBS students of IPGME&R, Kolkata after getting an approval from the Institutional Ethics Committee (IEC).

2.2 Inclusion Criteria: Apparently physically and mentally fit, not doing any exercise, non-smoker, non-alcoholic, non-diabetics, not suffering from any respiratory or cardio-vascular disease.

2.3 Study population : According to BMI which was measured by Quetlet's index measuring height and weight, the subjects were divided into three groups: subjects with BMI up to 22.9 kg/m^2 were taken as normal or control group, BMI $\geq$23 kg/m^2 but $\leq$ 25 kg/ m^2 as overweight group and BMI $\geq$ 25 kg/m^2 as obese group[23,24],this is different from WHO cut-off point[25].The range of Body fat percentage for fitness is 14–17% in males and 21–24% in females (according to American Council on Exercise) [26,27].But these values vary from study to study and dependent on the methodology adopted. For this study, both the male and female subjects were divided into two groups: the Body fat % < 17% in males was taken as normal and the Body fat % ≥17% was taken as overweight. Similarly in females the Body fat % < 24% were taken as normal whereas Body fat % ≥ 24% were taken as overweight.

2.4. Method: All subjects were informed about the test and a written consent was obtained. Standing body height (BH) was measured without shoes and with light clothes to the nearest of 0.1 cm with the help of a wall-mounted graduated wooden scale[28]. Body weight (BW) was measured to the nearest of 0.1 kg with the help of a bathroom type weighing machine [28]. Body mass index (BMI) was calculated from height and weight. Thus BMI was obtained using the formula of Quetlet's index [weight (kg)/height^2 (meter)].Body fat %was calculated by Jackson & Pollack (JP) formula. According to this formula, the sum total of skin fold thickness measurements at 7 sites (triceps, biceps, thigh, calf, subscapular, supraspinale and abdominal areas using skinfold Vernier calliper) were divided by subject's body weight in pound (lb) and this was multiplied by 0.27 and got the value of body fat %[29] . The skin fold was picked up between the thumb and the forefinger and the calipers were applied 1 cm below and at right angles to the skin pinch and the readings were taken 5 seconds after the caliper was applied. Three consecutive readings were taken and recorded at each site. The difference was not more than 2 mm between them.The average of the three readings at each site was calculated[31].Pulmonary function tests were done by Medspiror, an electronic spirometer for measuring dynamic lung functions. After rest for 5–10 min and briefing to the technique of FVC (maximum inhalation followed by maximum exhalation) and MVV (voluntary hyperventilation for 12 seconds), tests were carried out in a private and quiet room, in a standing position with the nose clip held in position on the nose.

2.5. Spirometric parameters recorded:

FVC: Forced Vital Capacity in Litres/second
FEV_1: Forced Expiratory Volume in one second in Litres
FEV_1/FVC: Ratio of Forced Expiratory Volume and Forced vital Capacity in %
MVV: Maximum Voluntary Ventilation in Litres
PEFR: Peak Expiratory Flow Rate in Litres/min.

2.6. Statistical Analysis:

Statistical analyses were done with Graph Pad Prism5.Values were expressed as mean ±SD. Data were analyzed by independent groups't-test between means. Pearson's correlation coefficient was calculated to determine the relationship between BMI &body fat% with pulmonary function parameters.

III. Result and Analysis

Table 1: Distribution of PFTs according to their mean ± SD values in relation to BMI in Males

PFTs	Control (n=26) Mean± SD	Overweight(n=11) Mean ± SD	P value	Control (n=26) Mean ± SD	Obese (n=13) Mean ±SD	P value
FVC(L/sec)	3.748 ± 0.22	3.955 ± 0.24	0.016	3.748 ± 0.22	3.29 ±0.39	0.0000***
FEV_1(L/sec)	3.039 ± 0.29	3.376 0.32	0.003	3.039 ± 0.29	2.35± 0.49	0.0000***
FVC/FEV_1	0.811±0.07	0.853 0.05	0.083	0.811±0.07	0.69 ± 0.06	0.0000***
PEFR(L/sec)	4.611± 1.74	5.448 1.86	0.19	4.611± 1.74	5.21± 2.2	0.359
MVV(L/min)	114.29 ± 16.75	98.44 14.77	0.01	114.29 ± 16.75	98.97± 12.73	0.0000***

Table 1 shows that FVC, FEV_1, FEV_1/FVC and PEFR were greater in overweight than normal males; but they were much lower in obese than normal males except PEFR which was increased in overweight and obese and this decrease was found to be highly significant statistically ($P<0.05$). MVV was decreased in both overweight and in obese than normal males and these changes were found to be statistically significant.

Table 2: Distribution of PFTs according to their mean ± SD values in relation to BMI in Females

PFTs	Normal mean±SD (n=31)	Overweight mean±SD (n=12)	P value	Normal mean±SD (n=31)	Obese mean±SD (n=7)	P value
FVC (L/Sec)	2.85 ± 0.20	2.95 ± 0.24	0.1828	2.85 ± 0.20	2.098 ± 0.19	0.0000***
FEV_1(L/Sec)	2.25 ± 0.23	2.44 ± 0.29	0.027*	2.25 ± 0.23	1.43 ± 0.22	0.0000***
FEV_1/FVC	0.79 ± 0.04	0.83 ± 0.08	0.0428*	0.79 ± 0.04	0.68 ± 0.059	0.0000***
PEFR(L/Sec)	2.34 ± 1.05	3.56 ± 0.95	0.0011**	2.34 ± 1.05	2.57 ± 0.98	0.6069
MVV(L/Min)	85.97 ± 9.27	74.37 ± 11.34	0.0013	85.97 ± 9.27	47.96± 9.53	0.0000***

Table 2 shows that in relation to BMI, FVC, FEV_1 and FEV_1/FVC were greater in overweight than normal females; but were much lower in obese than normal females and this decrease was highly significant statistically ($P<0.05$).There was also a significant increase in FEV_1 and FEV_1/FVC in overweight than normal. PEFR was greater in overweight than normal and slightly greater in obese than normal females. The increase in PEFR in overweight was statistically significant. MVV was decreased in overweight and obese than normal, both were found to be statistically significant.

Table 3: Distribution of PFTs according to their mean ±SD values in relation to Body fat % in Males

PFTs	Normal(n=35) Mean ±SD	Overweight (n=15) Mean ±SD	P value
FVC (L/Sec)	3.846 ± 0.19	3.26 ± 0.34	0.0000***
FEV1(L/Sec)	3.14 ± 0.37	2.45 ± 0.48	0.0000***
FEV1/FVC	0.808 ± 0.07	0.75 ± 0.11	0.0328*
PEFR(L/Sec)	4.752 ± 1.72	5.336 ± 2.28	0.3235
MVV(L/Min)	106.95 ± 20.41	89.22 ± 18.18	0.0056**

Table 3 showed that in relation to body fat %, all PFTs except PEFR were significantly decreased ($P<0.05$) in overweight males than normal males .PEFR showed non- significant increase in overweight males.

Table 4: Distribution of PFTs according to their mean ±SD values in relation to Body fat % in Females

PFTs	Normal (n=31) Mean ±SD	Overweight (n=19) Mean ±SD	P value
FVC (L/Sec)	2.906±0.22	2.546±0.39	0.0001***
FEV_1(L/Sec)	2.32 ± 0.27	1.95 ± 0.46	0.0007**
FEV_1/FVC	0.798±0.06	0.755±0.08	0.0410*
PEFR(L/Sec)	2.656±1.17	2.685±1.08	0.9304
MVV(L/Min)	82.51 ±11.58	70.29±19.99	0.0085*

According to Table 4, body fat % overweight females showed a highly significant decrease in FVC and FEV_1 and a lesser significant decrease in FEV_1/FVC and MVV. PEFR did not show any significant change.

Table 5: Distribution of Pearson's correlation coefficient of different PFTs with BMI and Body fat % in Male

Spirometric indices	BMI		Body fat%	
	Pearson's correlation coefficient(r)	P value & is the correlation significant?	Pearson's correlation coefficient(r)	P value & is the correlation significant?
FVC	-0.4422	0.0013** Yes	-0.9398	0.0001*** Yes
FEV1	-0.4871	0.0003*** Yes	-0.7648	0.0001*** Yes
FEV_1/FVC	-0.4642	0.0007*** Yes	-0.3929	0.0048** Yes
PEFR	0.2338	Non-significant No	0.1364	Non-significant No
MVV	-0.5219	0.0001*** Yes	-0.4710	0.0006*** Yes

By Pearson's correlation analysis, BMI showed negative (inverse) correlations with FVC,FEV_1, FEV_1/FVC and MVV in males of which MVV showed strongest correlation (r=-0.5219; P=0.0001) than other variables. PEFR did not show any significant correlation with BMI. Body fat% in males showed a stronger significant negative correlation with FVC and FEV_1 whereas MVV and FEV_1/FVC also showed a significant inverse correlation but to a lesser degree.

Table 6: Distribution of Pearson's correlation coefficient of different PFTs with BMI & Body fat % in Female

Spirometric indices	BMI		Body fat%	
	Pearson's correlation coefficient(r)	P value & is the correlation significant?	Pearson's correlation coefficient(r)	P value & is the correlation significant?
FVC	-0.5472	<0.0001*** Yes	-0.5298	<0.0001*** Yes
FEV1	-0.5211	0.0001*** Yes	-0.4866	0.0003*** Yes
FEV1/FVC	-0.4198	0.0024** Yes	-0.2908	0.04* Yes
PEFR	0.0935	Non-significant No	0.1298	0.01* Yes
MVV	-0.7322	<0.0001*** Yes	-0.2420	Non-significant No

By Pearson's correlation analysis, BMI showed negative (inverse) correlations with all PFTs except PEFR in females. But here MVV showed strongest correlation (r= -0.7322,P<0.0001) compared to others. PEFR did not show any significant correlation with BMI .Body fat % in females showed a significant negative correlation with FVC, FEV_1,FEV_1/FVC. But FVC showed the strongest association with body fat %. Interestingly here MVV did not show any significant correlation.

IV. Discussion :

It is globally accepted that obesity is a health hazard because of its strong association with numerous complications including respiratory diseases. Obesity cannot be assessed by body weight alone as desirable body weight is different from person to person. So different anthropometric measurements have been used to define obesity levels. As a measure of overall obesity, BMI is a good index. Unfortunately BMI does not give any indication of fat distribution[25]. But BMI also does not take into account of the pattern of fat distribution and its use is valid only for lung function indices where the contribution of fat and muscles are synergistic. So the other obesity marker that was studied was body fat %.

Table 1 and 2 showed that the mean values of PFTs and their statistical significance in relation to BMI in males and females respectively .The FVC, FEV_1, FEV_1/FVC ratio were increased in overweight (BMI≥ 23Kg/m^2 ≤ 25 kg/ m^2) in both sexes but they were significantly decreased with respect to normal group in obese (BMI ≥25 Kg/m^2) in both sexes. The MVV was significantly decreased in both the groups in both sexes while PEFR showed an increased value in both the groups though it was not statistically significant.

Lazarus R et al in 1998[11], reported a significant decrease in FVC in the obese group and in 2004 , Zeid Rasslan et al[31] in his study in Brazilian subjects found a non-significant decrease in FVC in obese group**.**Yue Chen et al in 2007[32] , have reported a decreased FVC & FEV1 in overweight & obese subjects and Anuradha R. Joshi et al in 2008[33], showed a significant reduction in FVC & MVV in obese in both sexes. Yogesh Saxena et al in 2009[34] in his study in young adults found a decreased FVC & FEV1 in relation to BMI only in obese females.In 2003 D. Chan et al[35] in his study in children of age group 6-18yrs has said that classically, obesity does not affect spirometric values other than MVV and only when BMI is > 45 there is reduction in FVC & FEV1. Muralidhara et al in 2007[36], could not find any significant difference in FVC,FEV1 & PEFR when BMI was considered and in 2008 D. Costa[37] in his study, on adults found no statistical difference between obese & non-obese group with regard to VC, FVC. FEV1 but obese group had a lower MVV.In 2008, Yogesh Saxena et al[38] studied a group of volunteers in the age group 20-40years and did not find any significant difference in FVC,FEV1, FEV1/FVC ratio between obese & non- obese males with BMI >30. In 2010, Yogesh Saxena et al[39] has shown a significant lowered PEFR in obese males but only in the higher age group.

In this study, FVC and FEV_1 were increased in overweight individuals having BMI ≥ 23 kg/m$^2 \leq$ 25 kg/m^2 in both sexes but it was decreased in the obese group. This can be explained by the fact that with weight gain, there is a related increase in muscle strength and so pulmonary function initially increases in parallel with weight gain though subsequently increase in body weight would reduce lung function due to obesity effect[19].

The PFTs in relation to body fat% in males and females showed a significant decrease in FVC, FEV_1 (Table3and 4) .Though the decrease in FEV_1/FVC ratio was slightly significant compared to normal group ,but value was within normal limits (75%). MVV was decreased significantly in both sexes while PEFR showed a non-significant increase. Anuradha R Joshi et al[33] found a significant reduction in FVC, FEV_1, PEFR & MVV in obese males with a higher body fat % while in females there was a significant reduction in FVC, MVV & PEFR. Muralidhara et al in 2007[36] found no significant difference in FVC, FEV_1 and PEFR when body fat % was considered. Both FVC and FEV_1 are the lung functions most closely related to body composition and fat distribution. They observed the values of decreased FVC & FEV_1 with increased body fat %, suggests that displacement of air by fat within the thorax and abdomen. Lack of association of body fat % with low FEV_1/FVC ratio suggests that inspiratory and expiratory muscle strength is normal [40] and body fat distribution has no significant effect on flow rate. This is consistent with the findings from the third National Health & Nutrition Exam Survey [41] .

In the present study, the PEFR showed a non significant increased value in the overweight group in all categories in both sexes. All the dynamic functions of the lung depend on the compliance of the thorax-lung system, airway resistance & muscular strength of the respiratory muscles[42].

The primary factors that affect PEFR are the strength of the expiratory muscles or the force of contraction, the elastic recoil pressure of the lungs & airway size[43] .PEFR may not be the most suitable variable to detect the early deterioration of the ventilatory functions [44].The increase in PEFR could be attributed to the fact that the study population comprised of healthy, young individuals having strong ventilatory muscles and high motivation & enthusiasm may have overcome the deficits, even if they had existed. MVV test evaluates the respiratory endurance & is influenced by the respiratory muscle strength, lung & chest compliance, control of airway breathing & airway, resistance[45,46]. In case of obese individuals, this variable is reduced mainly by mechanical injury to the respiratory muscles caused in particular by excessive weight on the thorax.

From the Pearson Correlation analysis in males (Table5) we find that BMI showed an inverse correlation with FVC, FEV1, FEV1/FVC ratio, MVV and MVV showed the strongest correlation than the variables. Whereas body fat % in males showed a stronger significant negative correlation with FVC & FEV1 that with FEV1/FVC ratio and MVV.

In females, (Table 6) too ,BMI showed an inverse correlation with FVC,FEV_1, FEV1/FVC ratio, MVV but the strongest was with MVV. Body fat % in females showed strong negative correlation with FVC, FEV_1 but interestingly MVV did not show significant correlation.

S Goya Wannamethee et al in 2005[47] in his study in elderly men showed that BMI was inversely correlated with FVC & positively correlated with FEV1/FVC ratio.Body fat % showed inverse correlation with FVC and FEV_1. Y. Saxena et al in 2009[48] showed a significant negative correlation between BMI & FVC & FEV1 only in females[38] .Costa D et al in 2008[37] ,in his study on adult women showed moderate negative correlation of BMI with MVV and Yue Chen et al in 2007[32] showed an inverse association of BMI with FVC, FEV1 in both sexes which is similar to our study. Contrary to our study, Slawomir Koziel et al in 2007[49], found a positive association of BMI with FVC. Anuradha R. Joshi et al in 2008[33] found a negative correlation of body fat% with FVC, FEV_1, PEFR, MVV in males and with FVC, PEFR, MVV in females. In this study, in males, BMI is maximally correlated with MVV while FEV_1, FEV_1/FVC ratio. Body fat % is maximally correlated with FVC & FEV1.

In females, BMI is maximally correlated with FVC, FEV1 & MVV. Body fat% is maximally correlated with FVC & FEV1. Yue Chen et al in 2007[32] found a consistent negative association of BMI with pulmonary function in overweight subjects in both sexes. Y. Saxena, et al in 2008[38], found strong negative correlation of BMI with PFTs in females only while Costa D, et al in 2008[70] found a lowered MVV in females with high BMI.

These findings are consistent with our study where we find that in females, BMI is a good obesity index for FVC, FEV_1, FEV_1/FVC, MVV. But in males, our study shows that BMI is a better index only for MVV.

Anuradha R. Joshi et al in 2008[33] in her study has indicated that increase in body fat % shows modest decrease in dynamic tests though the magnitude of the effect was relatively small.

V. Conclusion

We were able to analyze the contribution of different obesity markers to variation in pulmonary function. From this study it can be concluded that abdominal obesity, by exerting an excessive weight on the thorax reduces the expansion of the chest. This is not so marked for FVC or FEV_1 as these are a single breath tests and the subjects were young, could be motivated and not highly obese but it becomes prominent while performing MVV which is an endurance test done for a span of 12 seconds .

Females showed a greater correlation of the PFTs with BMI than males which can be due to lesser respiratory muscle strength & therefore producing lower dynamic compression.

FVC and FEV_1 are the lung functions most closely related to body composition and fat distribution and we have observed that increase in body fat % is a good predictor of decline in FVC and FEV1 than BMI in both sexes. Lastly, PEFR may not be a suitable variable to detect the early deterioration of the ventilatory functions.

Our study was a random sample of individuals from only a segment of the population. A larger sample size & a longitudinal study will definitely be of a greater value in predicting the relationship between PFTs & the different obesity markers.

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