ORIGINAL ARTICLE

Effect of Body Fat Distribution on Pulmonary Functions in Young Healthy Obese Students

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Abstract:

Background: Obesity is defined as "abnormal or excessive fat accumulation that may impair health". WHO defines obesity as Body Mass Index (BMI) ≥ 30 Kg/m^2. Obesity is becoming more prevalent in the world and has effects on different body systems. Main is the impact on respiratory function. *Aim & Objectives*: We have aimed to study the gender difference in obesity induced changes on pulmonary functions and determine adiposity marker which best predicts the pulmonary function in young adult obese individuals and age-matched non-obese young adult subjects. *Materials and Methods:* A cross sectional study was conducted on obese (BMI ≥ 30 kg/m^2) male (n=32) and female (n=18) students aged 18-25 years and compared with age matched non-obese (BMI 18.5–24.99 Kg/m^2) male (n=23) and female subjects (n=27) as controls. Weight(kg), Height(cm), Body Mass Index(BMI, kgm^{-2}), Waist Circumference(WC, cm), Waist to Hip Ratio(WHR),Waist to Height Ratio (WHtR), Forced Vital Capacity (FVC, L), Forced Expiratory Volume in first second (FEV_1, L/min), $FEV_{1\%}$, $FEF_{25-75\%}$ (L/sec), Peak Expiratory Flow Rate (PEFR, L/min) and Maximum Expiratory Pressure (MEP, mm Hg) were recorded. *Results:* Systolic Blood Pressure, Diastolic Blood Pressure, Pulse Rate and Respiratory Rate were significantly higher in obese students when compared to their respective controls. We observed highly significant reduction in PEFR ($p<0.001$) and MEP ($p<0.001$) in both obese male and female groups compared to controls. $FEV_{1\%}$ was significantly lower in obese female students. Linear regression analysis revealed that BMI, WHR and WC were significant predictors of PEFR. BMI was only the significant predictor of MEP. WHtR and WHR were best predictors of FVC, $FEF_{25-75\%}$ and FEV_1. *Conclusion:* Obesity and pattern of fat distribution have independent effect on pulmonary function.

Keywords: Pulmonary Functions, Obesity, Fat distribution

Introduction:

Obesity is one of the most frequently found health risks and its prevalence appears to be increased all over the world because of physical inactivity and westernized diet [1].Weight and Body Mass Index (BMI) as measures of overall adiposity are used as predictors of pulmonary function in many epidemiologic studies. These measures are widely accepted as determinants of pulmonary function. Abdominal adiposity may influence pulmonary function through a mechanism that is distinct from that of overall adiposity. Truncal obesity reduces chest wall compliance, respiratory muscle function and peripheral airway size [2, 3].

In obese adults, the most frequently reported abnormalities are reductions in lung volumes and expiratory flow rates [4].Pulmonary function tests permit accurate assessment of the functional state of the respiratory system and allow quantification of the severity of disease, thereby enabling early detection, assessment of the natural history and response to therapy. The pattern of pulmonary function is found to worsen with the degree of obesity moving from a restrictive pattern in mild to moderate obesity with both Forced Expiratory Volume in first second (FEV_1, L/min) and Forced Vital Capacity (FVC, L), reduced and FEV1/FVC ratio being normal to an obstructive pattern in severe and morbid obesity with significant decrease in FEV1 as against FVC andFEV1/FVC ratio being decreased [5, 6].

A study was conducted in general population of Amritsar on 100 obese and 100 non obese male individuals, showed decreased FVC and FEV_1 in obese as compared to non obese individuals [7].

In previous studies, they reported that only reduction in pulmonary function parameters in obese subjects, but which adiposity marker best predicts pulmonary function is not properly conveyed [5-9]. Hence, the aim of the study was to evaluate the effect of obesity on pulmonary functions and to determine adiposity marker which best predicts the pulmonary function in obese subjects of South Indian aged 18-25 years.

Materials and Methods:

The present comparative study was conducted on obese male students (n=32, BMI ≥30kg/m^2) aged 18-25 years and compared with age matched non obese male controls (n=23, BMI 18.5–24.99kg/m^2). Similarly, obese female students (n=18, BMI >30kg/m^2) aged 18-25 years and compared with age matched non obese female controls (n=27, BMI 18.5–24.99kg/m^2) of KCP Science college, Vijayapur. Duration of study was from December 2013 to May 2014. Institutional ethics clearance was obtained.

Subjects with history of asthma, diabetes mellitus, hypertension, other cardiovascular diseases, endocrine disease or surgery, on chronic medication, smokers, alcoholics, with noticeable weight gain or weight loss over the preceding 3 months were excluded from study. Blood pressure was measured by mercury sphygmomanometer in lying down posture comfortably on bed after 10 minutes of rest. An average of 3 blood pressure readings has been taken.Height (centimeters, cm) and Weight (Kilograms, kg), Waist Circumference (WC, cm) and Hip Circumference (HC, cm) were recorded. BMI (kg/m^2), Waist to Hip circumference and Waist to Height ratio of both study and control groups were calculated. Pulse Rate (beats per minute, bpm), Respiratory Rate (cycles per minute, cpm), Systolic Blood Pressure (SBP, mmHg) and Diastolic Blood Pressure (DBP, mmHg) were also recorded. The subjects were informed regarding the procedure. Demonstration was given by investigator in regard of recording of various pulmonary function tests by using Spiropac (MEDICAID) systems Ltcl, India. The readings were taken in a comfortable upright sitting position in each individual. Forced Vital Capacity (FVC, L), Forced Expiratory Volume in first second (FEV_1, L/min) determine large airway lung functions, FEV_1%, Forced Expiratory Flow at 25%-75% of Forced Vital Capacity ($FEF_{25-75\%}$, L/sec) determines small airway function of lungs. Peak Expiratory Flow Rate (PEFR, L/min) and Maximum Expiratory Pressure (MEP, mm Hg) were recorded [10].

Statistical Analysis:

It is done by using SPSS software 16 version. All observations were expressed as mean ± SD (Standard Deviation). Significance of difference between the study and control groups was determined using student's unpaired “t” test. Correlation between adiposity markers (BMI, WC, WHR, WHtR) and pulmonary functions was done using Pearson's correlation. Step Wise Linear Regression analysis was done to find the association with adiposity markers that could best predict pulmonary functions.

Results:

Anthropometric and Physiological Parameters:

Table 1 shows anthropometric parameters such as age, weight, height, BMI, WC, HC, WHR, WHtR, Pulse rate, Respiratory rate, Systolic and Diastolic blood pressure of male and female study groups compared with their respective controls and were expressed in Mean ± SD. The non-obese and obese male and female groups had similar age and height. There was a significant increase in weight, BMI, WC, WHR, WHtR, Pulse rate, Respiratory rate, and Systolic and Diastolic blood pressure in obese males and females groups compared to their respective control groups.

Table 1: Anthropometric and Physiological Parameters

	Females			Males		
Parameters	**Control Group (N=18)**	**Study Group (N=27)**	**p value**	**Control Group (n=32)**	**Study Group (n=23)**	**p value**
Age (Years)	20.27 ± 2.42	20.14 ± 1.99	0.835	20.37± 1.93	21.34 ± 2.42	0.118
Height (cm)	159.05 ± 9.07	153.96±7.09	0.54	165.34 ± 8.82	162.21 ± 6.61	0.139
Weight (kg)	53.77 ± 7.15	72.14 ± 6.56	0.000*	57.87 ± 8.00	79.17± 7.81	0.000*
BMI (kg/ m^2)	21.20± 1.23	30.37±0.897	0.000*	20.97 ± 1.53	30.41± 1.26	0.000*
WC(cm)	84.11±6.12	102.37±6.10	0.000*	82.18±9.19	98.82±9.93	0.000*
HC(cm)	108.05±9.50	112.51±4.85	0.079	104.06±12.15	106.82±8.96	0.970
WC/HC	0.77± 0.002	0.90± 0.003	0.000*	0.78 ± 0.004	0.91 ± 0.003	0.000*
WC/Ht	0.52 ± 0.004	0.63 ± 0.004	0.000*	0.49 ± 0.005	0.60 ± 0.006	0.000*
Pulse Rate (bpm)	72.66 ± 5.42	86.29 ± 5.84	0.000*	74.62± 4.96	84.47± 6.44	0.000*
Respiratory Rate (cpm)	13.38 ± 1.57	21.66 ± 1.81	0.000*	13.96 ± 2.54	21.43 ± 2.17	0.000*
SBP (mmhg)	114.88 ± 8.37	129.25 ± 7.80	0.000*	115.06 ± 9.00	136.08 ± 10.33	0.000*
DBP (mmhg)	74.22 ±5.61	84.44 ±6.40	0.000*	73.93 ± 6.37	85.21 ± 6.65	0.000*

Data are presented as mean ± SD. BMI- Body Mass Index, SBP- Systolic Blood Pressure, DBP-Diastolic Blood Pressure, bpm- beats per minute, cpm-cycles per minute.
**indicates level of significance, p<0.01*

Respiratory Parameters:

Table 2 shows reduction in FVC, FEV1, FEV1%, FEF 25-75%, PEFR, MEP in obese males and females compared to control. FEV1% ($p<0.05$) was significantly reduced in female study group compared to controls. PEFR ($p< 0.001$) and MEP ($p<0.001$) were significantly reduced in both female and male study groups compared to their respective control groups.

Table 2: Pulmonary Function Parameters

	Females			Males		
Parameters	**Control group (n=18)**	**Study group (n=27)**	**p value**	**Control group (n=32)**	**Study group (n=23)**	**p value**
FVC (L)	2.183± 0.67	2.180± 0.45	0.987	2.90± 0.58	2.83 ± 0.63	0.654
FEV_1(L)	1.99± 0.63	1.90 ± 0.55	0.636	2.60 ± 0.56	2.53 ± 0.63	0.678
FEV_1 %	93.20± 4.89	86.57± 14.90	0.039 *	91.44 ± 8.00	90.77± 9.74	0.790
$FEF_{25-75\%}$ (L/sec)	3.52± 1.19	3.77 ± 1.09	0.481	4.50 ± 1.19	4.67 ±1.44	0.657
PEFR (L/min)	452.7 ± 91.51	297.03 ± 78.48	0.000*	473.43± 103.16	339.13± 124.27	0.000*
MEP (mmHg)	59.77 ± 24.70	25.55± 14.13	0.000*	71.43 ± 31.86	28.69 ± 13.58	0.000*

*Data are presented as mean ± SD.*Indicates the level of significance ($p\leq0.05$)*

Bivariate Analysis:

Table 3 shows correlation of adiposity markers (BMI, WC, WHR, WHtR) with pulmonary functions. In present study, showed Forced Vital Capacity (FVC) and Forced Expiratory Volume in first second (FEV_1) were negatively correlated with adiposity markers and among them WC {FVC ($r = -0.253$, $p< 0.01$), FEV_1 ($r = -0.236$, $p <0.05$)}, WHtR {FVC($r = -0.357$, $p< 0.001$), FEV_1 ($r = -0.319$, $p < 0.01$)} were statistically significant. Present study showed significant negative correlation of Forced Expiratory Flow at 25%-75% of Forced Vital Capacity ($FEF_{25-75\%}$), Peak Expiratory Flow Rate (PEFR) and Maximum Expiratory Pressure (MEP) with all adiposity markers.

Table 3: Bivariate Analysis of Adiposity Markers with Pulmonary Functions

Parameter	FVC	FEV_1	$FEV_{1\%}$	$FEF_{25-75\%}$	PEFR	MEP
	r (p value)	r (p value)	r (p value)	r (p value)	r (p value)	r (p value)
BMI	-0.120 (0.236)	-0.130 (0.198)	-0.168 (0.09)	0.173 (0.02)*	-0.58* (0.000)	-0.66* (0.000)
WC	-0.253* (0.011)	-0.236* (0.018)	-0.163 (0.09)	0.316 (0.001)*	-0.358* (0.000)	-0.455* (0.000)
WHR	-0.065 (0.518)	-0.039 (0.697)	-0.068 (0.501)	0.175 (0.01)*	-0.585* (0.00)	-0.603* (0.000)
WHtR	-0.357* (0.000)	-0.319* (0.001)	-0.116 (0.250)	0.389 (0.00)*	-0.386* (0.000)	-0.492* (0.000)

*r is correlation, * indicates level of significance($p< 0.05$)*

Stepwise Linear Regression Analysis:

Table 4 shows stepwise linear regression analysis. BMI, WC, WHR and WHtR were independent variables and FVC, FEV_1, $FEF_{25-75\%}$, PEFR, MEP were dependent variables. Among adiposity markers, WHR {FVC (β= 0.370, p= 0.005), FEV1 (β= -0.578, p< 0.001), FEF $_{25-75\%}$ (β= -0.319, p= 0.01)}and WHtR {FVC (β= -0.618, p< 0.01), FEV1 (β= 0.368 p= 0.006), FEF $_{25-75\%}$ (β= -0.518, p= 0.002)} were significant predictors of FVC, FEV1, FEF $_{25-75\%}$. BMI (β = -0.0415, p = 0.007), WC (β = -0.263, p = 0.035) and WHR (β = -0.432, p = 0.006), were significant predictors of PEFR and BMI (β = -0.66, p <0.001) was only the significant predictor of MEP.

Table 4: Stepwise Linear Regression Analysis

Parameters	FVC β (p value)	FEV_1 β (p value)	$FEF_{25-75\%}$ β (p value)	PEFR β (p value)	MEP β (p value)
BMI	0.062 (0.729)	-0.079 (0.66)	-0.028 (0.16)	-0.0415 (0.007)*	-0.66 (0.000)*
WC	0.449 (0.097)	0.289 (0.310)	-0.038 (0.08)	-0.263 (0.035)*	0.06 (0.573)
WHR	0.370 (0.005)*	-0.578 (0.000)*	-0.319 (0.011)*	-0.432 (0.006)*	-0.150 (0.279)
WHtR	-0.618 (0.000)*	0.368 (0.006)*	-0.518 (0.023)*	-0.229 (0.373)	-0.023 (0.834)

Dependent variables- FVC, FEV_1,$FEF_{25-75\%}$, PEFR, MEP and independent variables- BMI, WC, WHR, WHtR.

**Indicates the level of significance ($p\leq 0.01$)*

Discussion:

Lung functions are significantly related to power of abdominal muscles and upper body fat percentage. In literature, it was stated that lung functions are under the influence of muscularity and fat distribution rather than body weight. BMI determines overall adiposity where as WC and WHR determine abdominal adiposity [8].

Obesity might impair pulmonary function via several mechanisms. The increased adiposity around ribs, diaphragm and abdomen leading to limited movement of ribs, decreased total thoracic and pulmonary volume causes reduction in chest wall compliance and preventing full excursion of the diaphragm. There are also effects of obesity on upper airway tone [9, 10]. Resistance as well as mechanical load will be increased which in turn increases the work of breathing. Obese individuals have an increased demand for ventilation and respiratory muscle inefficiency, decreased functional residual capacity and expiratory reserve volume and closure of peripheral lung units. It adversely affects chest wall mechanics and causes a decrease in total respiratory compliance due to deposition of subcutaneous adipose tissue [6].

In present study WC, WHtR were significantly negatively correlated with FVC and FEV_1. Linear regression analysis showed WHtR, WHR were significant predictors for FVC and FEV_1. In a study conducted by Helala *et al*, they observed significant negative correlation between WC and FVC in obese group. With average 1 cm increase in WC was associated with 20ml reduction in FVC. WC was significantly negatively associated with FEV1 in obese group. With increase in 1cm of WC was associated with 13ml reduction in FEV1 [11]. Robert *et al* concluded that obese men showed more impairment of FVC with weight gain than obese women, estimated reduction of FVC was 17ml/kg weight gain for men and 10ml/kg for women [12].

BMI is negatively correlated with FEV_1 but not significant, suggesting restrictive pattern and might be due to inclusion of young aged adults and less number of subjects and this finding is corroborated with the study of Behera *et al* [10]. Helela *et al* study showed similar finding but was significant in obese group. A reduction in absolute value of FEV_1 indicates airway narrowing. Hence, FVC and FEV_1 are more affected by abdominal adiposity in the present study.

We have observed significant reduction in $FEV_{1\%}$ only in obese females compared to controls and BMI, WC, WHR, WHtR showed nonsignificant negative correlation with $FEV_{1\%}$. Abdominal adiposity may influence $FEV_{1\%}$ but in present study did not get significant predictor of it, may due to inclusion of less number of subjects. Similar findings were observed by Chen *et al* [2], Canoy *et al* showed nonsignificant negative correlation of WC with $FEV_{1\%}$ [14].

We observed significant negative correlation of adiposity markers with Forced Expiratory Flow at 25%-75% of Forced Vital Capacity ($FEF_{25-75\%,}$ L/sec) and findings were similar to Helala *et al* study. On stepwise linear regression analysis we found that WHR, WHtR were significant predictors of $FEF_{25-75\%}$. Similar results by JE Park *et al* showed WHR increased by 0.01 leads to reduction of $FEF_{25-75\%}$ by 88.1 ml [15]. Therefore $FEF_{25-75\%}$ is more affected by abdominal adiposity.

In our study PEFR is negatively correlated with adiposity markers. Shenoy *et al*, Mahajan *et al*, Sonu Ajmani [7, 16-19] observed similar findings. Viger *et al* showed strong negative correlation between BMI and PEFR. Stepwise linear regression analysis showed BMI, WHR and WC were significant predictors of PEFR. Our finding was similar to Saxena *et al* who reported PEFR was negatively associated with adiposity markers and on multivariate analysis, WHR found to be most significant parameter that showed significant negative association with PEFR. Hence PEFR is affected by both overall and abdominal adiposity. Lower values of PEFR could be linked to mechanical effect of obesity on diaphragm and also because of fat deposition between the muscles and ribs that can lead to increase in metabolic demands and work of breathing [20-25]. In our study, MEP was significantly reduced in both female and male study groups compared to their respective control groups and significant negative correlation with adiposity markers. BMI was only the significant predictor of MEP in present study. Choudary *et al* in their study found that MEP was found to be positively correlated in both sexes [26]. Our findings indicate the consequence of increased abdominal obesity on pulmonary functions.

Limitation of the study :

The sample size was small and the dietary habits of the individuals under study were not evaluated.

Conclusion :

The study concludes that all the respiratory parameters were significantly reduced equally in both males and female obese subjects compared to their respective non-obese subjects. FVC, FEV_1 and $FEF_{25-75\%}$ are best predicted by WHR, WHtR. BMI, WC and WHtR are best predictors of PEFR. MEP is best predicted by BMI. Obesity and pattern of fat distribution have independent effect on pulmonary function.

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References

1. World Health Organization (WHO). Obesity: preventing and managing the global epidemic.WHO Technical Report Series No.894, Geneva: WHO, 2000
2. Chen Y, Rennie D, Cormier Y, Dosman J. Waist circumference is associated with pulmonary function in normal weight, overweight and obese subjects. *Am J Clin Nutr* 2007;85:35-39
3. Ceylan E, Comlekci A, Akkoclu C, Itil O, Ergor G. The effect of body fat distribution on pulmonary tests in overweight and obese. *South Med J* 2009; 102(1):30-35.
4. Raison J, Cassuto D, Orvoen-Frija E. Disturbances in respiratory function in obese subjects. In: Ailhaud G, editor Obesity in Europe 91 Proceedings of the 3rd Congress on Obesity. London. John Libbey and Company Limited 2001: 227-30.
5. Sahebjami H and Gartside PS. Pulmonary Function in Obese Subjects with a Normal FEV1/FVC Ratio. *Chest* 1996;110:1425-29
6. Koenig SM. Pulmonary complications of obesity: a review. Am J Med Sci 2001; 321:249-279.
7. Mahajan S, Arora AK, Gupta P. Obesity and spirometric ventilatory status in adult male population of Amritsar. *National Journal of Physiology, Pharmacy and Pharmacology* 2012; 2: 93 – 8.
8. Saxena Y, Purwar B, Upmanyu R. Adiposity: Determinant of Peak Expiratory Flow Rate in Young Indian Adult Males. *The Indian Journal of Chest Diseases and Allied Sciences* 2011; 53: 29-33.
9. Kumar Durgesh et al. Spirometric evaluation of lung functions in obese and non obese subjects. *Journal of Advance Researches in Biological Sciences 2013*
10. Behera AA, Behera BB, Dash S, Mishra S. Effect of body mass index on gender difference in lung functions in Indian population. *International Journal of Clinical and Experimental Physiology* 2014; 1:229-31.
11. Moncada J, Jose: *Body Fat Predicts Forced Vital Capacity in College Males. European Journal of Sport Science 2003; 3:1-11*
12. Helala L, Wagih K, Ablelmonem: Study of relation between body mass index, waist circumference and spirometry in COPD patients. *Egyptian Journal of Chest Disease of Tuberculosis* 2014; 63:321-27.
13. Robert A, Wise, Enright P L, Connet E J, Nicolas R: effect of weight gain on pulmonary function after smoking cessation in lung health study. *Am J Respir Crit Care Med* 1998; 157:866-72.
14. *HU Y-H,* Reilly KH, Liang Y-J, Xi B, Liu J-T, Xu D-J, Yan Y-K, Xie B, Li X-Y. Increase in Body Mass Index, Waist Circumference and Waist-to-height Ratio is Associated with High Blood Pressure in Children and Adolescents in China. *The Journal of International Medical Research 2011; 39: 23 – 32*
15. Park JE, Chung JH, Lee KH, Shin KC. The Effect of Body Composition on Pulmonary Function. *Tuberc Respir Dis* 2012; 72:433-440.
16. Pal GK. Textbook of practical Physiology. Universities press, Hyderabad. 2010;3:153.
17. Kaur J, Singh M, Batra AP, Garg R, Kaur M, Punia N. Blood pressure and obesity variation among population of Amritsar district. *International Journal of Basic and Applied Medical Sciences 2013; 3:113-21*
18. Shenoy J, Shivakumar J, Deepti SK, Mirajkar A,

Muniyappanavar NS, Pai GP.Status of Pulmonary function in Indian young overweight male individuals. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* 2011; 4: 620-5.

19. Mahajan S, Arora AK, Gupta P Correlation of Obesity and Spirometric Ventilatory Status of adult female population of north India. *Advance Laboratory Medicine International*.2011; 1: 40 - 51.
20. Saxena Y, Sexena V, Divedi J, Sharma K R. Evaluation of dynamic function tests in normal obese individuals. *Indian J Physiol Pharmacol* 2008; 52: 375–82.
21. Sindhu CS. Obesity Assessment Based on BMI in the Young Adults of Haryana- a state of India. *Research Journal of Recent Sciences 2013;* 2: 304-7.
22. Costa D, Barbalho CM, Miguel Soares PG, Forti MP, Coutinho Azevedo LM.The impact of obesity on pulmonary function in adult women. *Clinics* 2008; 63:719-24.
23. Chatterjee P, Das P. Changes in Lung Function status of Adult Female over last one decade:A Cross-Sectional study in Kolkata, India. *International Research Journal of Environment Sciences 2013*;2: 30-34
24. Bishwalata R, Singh BA, Singh A, Devi LU, Singh BK. Overweight and obesity among schoolchildren in Manipur, India. *The National Medical Journal of India* 2010; 23:263-6.
25. Sarwari KM, Ali I, Jaleeli K A, Shanmukhappa NJ. Assessment of pulmonary function tests in young obese males and females in the age group of 18-25 years. *International Journal of Basic and Applied Medical Science* 2012; 2:185-9.
26. Choudhuri D, Choudhuri S. Effect of gender and body mass index on pulmonary function tests in adolscents of tribal population of north eastern state of India. *Ind J Phy Phar* 2014; 58:170-73.

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