# Body Mass Index and Dynamic Lung Volumes in Office Workers

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## ABSTRACT

**Objective:** To measure the association of body mass index (BMI) to lung volumes assessed by spirometer. **Study Design:** Cross-sectional analytical study.

**Place and Duration of Study:** Department of Physiology and Cell Biology, University of Health Sciences, Lahore, from February to August 2009.

**Methodology:** Two hundred and twenty-five apparently healthy adult office workers of either gender aged > 20 years were recruited. Height and weight were measured and BMI was calculated as kg/m<sup>2</sup>. Subjects were categorized as normal (BMI=18.5 to 24.9 kg/m<sup>2</sup>); overweight (BMI=25 to 29.9 kg/m<sup>2</sup>); and obese Class 1 (BMI=30 to 34.9 kg/m<sup>2</sup>) on the basis of BMI. Lung volumes were measured by digital spirometer and were reported as percentage of predicted values for forced vital capacity (FVC%), forced expiratory volume in first second (FEV<sub>1</sub>%) and ratio of FEV<sub>1</sub> to FVC (FEV<sub>1</sub>:FVC). Groups were compared using t-test and ANOVA, correlation was assessed by Pearson's 'r'.

**Results:** Significant differences in lung volumes were found in different BMI categories. Obese subjects had significantly lower FVC% (p < 0.0001), as well as significantly lower FEV<sub>1</sub>% (p = 0.003) as compared to normal subjects. There were significant linear relationships between obesity and PFTs. BMI had significant negative linear association with FVC% in overweight (r = -0.197) and obese (r = -0.488); and with FEV<sub>1</sub>% in obese subjects (r = -0.510). Gender and age had no significant effect on mean values of PFTs.

Conclusion: Obese individuals in this sample had significant decline in lung volumes.

Key words: Obesity. Body mass index. Pulmonary function tests. Spirometry.

## **INTRODUCTION**

Obesity has been known since ancient times. Avicenna recognized obesity as a disease and proposed guidelines for its cure, which remain the core component of weight reduction strategies to-date.<sup>1</sup> Obesity implies excess or abnormal accumulation of adipose tissue, to the extent that health may be impaired. Considering difficulty in direct measurement of body fat to define obesity, World Health Organization (WHO) recommends use of body mass index (BMI) for defining obesity.

Obesity is defined as  $BMI \ge 30 \text{ kg/m}^2$  and can be further classified upon the extent.<sup>2</sup> BMI is the simplest and most widely used index of adiposity. The validity of BMI in predicting body fatness is well-established in different age, gender and racial groups. BMI has been demonstrated to predict disease like hypertension, stroke, coronary heart disease (CHD), type-2 diabetes mellitus (T2DM) and certain cancers. It has also been proposed as an overall indicator of mortality as well.<sup>3</sup>

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The global epidemic of obesity often named as 'globesity' has also affected Pakistan and current subnational studies have reported an alarming presence of 28% overweight and 16% obese in Pakistanis.<sup>4</sup> Pakistanis have a higher proportion of total body fat and are at a greater risk of obesity related co-morbidities even at BMI cut-off point which are considered low risk for individuals in other countries.<sup>5</sup>

Obesity usually results in reduction in compliance of respiratory system leading to decrease in lung volumes resulting mostly in a restrictive type of ventilatory defect. Compression of thoracic cage by excessive fat and increased pooling of blood in pulmonary vasculature mainly contribute towards reduction in respiratory compliance.<sup>6</sup>

Researchers have linked BMI to changes in lung function.<sup>7</sup> Association between BMI and pulmonary function has been previously examined and BMI has been reported to be negatively associated with values for dynamic lung volumes including forced vital capacity (FVC) and forced expiratory volume in first second (FEV<sub>1</sub>).<sup>8</sup> However, to the best of authors' knowledge, this has not been previously studied in Pakistanis, who are believed to be at higher risk of complications of obesity.

Therefore, the present study was conducted to measure relationship between BMI and lung volumes in a officeworking sample of local population.

### METHODOLOGY

This was a cross-sectional study conducted at Department of Physiology and Cell Biology, University of Health Sciences, Lahore. Present study was approved by Ethical Research Committee and Advance Studies and Research Board of the University of Health Sciences, Lahore. The study was conducted during a period spanning February 2009 to August 2009. The subjects comprised of a convenience sample of 225 healthy volunteers aged > 20 years in Lahore city including 45 females and 180 males. The sample comprised of office workers at various administrative and support positions in government and private organizations mainly recruited from Packages Limited, Ferozpur Road, Lahore, Agricultural House, Davis Road and University of Health Sciences, Lahore.

Current, ex-smokers and users of tobacco in any other form (chewing, snuffing or water pipe) were excluded from this study. An ex-smoker was defined as someone who has smoked greater than 100 cigarettes in his/her lifetime, does not currently smoke, but used to smoke daily. Subjects with pre-existing pulmonary (e.g. tuberculosis, bronchial asthma, COPD etc.) or other systemic conditions (e.g. diabetes mellitus, hypertension, atopy, ascites etc.) were also excluded. Written informed consent was obtained from each participant prior to inclusion in the study. All data was recorded in a data collection proforma for each subject.

Anthropometric measurements were done by standard techniques.<sup>9</sup> To ensure correct measurement of height, subjects were asked to straighten their back and observer adjusted the head of the subject in Frankfort plane. Weight was measured by a spring weighing scale. All subjects were wearing light clothes during anthropometry to avoid error in measurement of weight. Subjects removed shoes before measurement of height and weight. BMI was calculated as kg/m<sup>2</sup> from height and weight. BMI was used as a measure of obesity and subjects were classified post-hoc into three categories (normal 18.5 - 24.9 kg/m<sup>2</sup>; overweight 25 - 29.9 kg/m<sup>2</sup>; and obese  $\geq$  30 kg/m<sup>2</sup>).<sup>2</sup>

Dynamic lung functions were measured by spirometry. We used a flow measuring type digital spirometer (Spirolab II, MIR srl, Rome, Italy). Measurements were done in accordance with the latest joint American and European guidelines which have replaced the older ATS and ERS guidelines respectively.<sup>10,11</sup> All recordings were made between 09:00 AM and 12:00 PM to avoid any presumed diurnal variations. The recordings were done in air-conditioned rooms with temperature between 20°C and 26°C to avoid large variations in humidity and temperature. Subjects were instructed regarding the correct way of blowing air into the spirometer and taking a deep breath before forceful expiration prior to the test. Spirometry of all subjects was done in proper sitting position for standardization and uniformity in interpretation of results. Nose clip was applied to all participants to avoid air leakage from nasal passages. A new disposable mouth-piece was attached to the spirometer before testing each participant. It was ensured that subjects sealed their lips tightly around the mouth-piece and blew out air as hard and fast as possible. The subject was actively encouraged during the procedure to breathe out as long as possible. Tests were discarded and repeated if subjects coughed or blocked the meter with their tongue. Test was repeated for three recordings that met the acceptability and reproducibility criteria and the highest reading was reported.<sup>10,11</sup> The procedure was abandoned if a participant was unable to produce an acceptable and repeatable spirogram after 8 attempts. Dynamic lung volumes were assessed as FVC, FEV1 (measured in litres) and ratio of FEV1 to FVC (FEV1:FVC; expressed as percentage).

There is a dearth of internationally acceptable reference values of lung function for Pakistani population.<sup>12</sup> For that reason, this study used spirometric reference values derived from Knudson *et al.*<sup>13</sup> To adjust for ethnicity, correction factors are applied to reference values. Predicted values for Pakistani population were adjusted by a factor of 0.90 (10% less than the values for Americans and Europeans).<sup>14</sup> Normal lung volumes for a particular individual were interpreted as percentage of predicted values. Lung volumes were reported as percentage of predicted value as a linear variable related to lung compliance possibly adjusted for the effects of age and gender.<sup>15</sup> Percent predicted values of FVC (FVC%) and FEV<sub>1</sub> (FEV<sub>1</sub>%) were used for analysis of spirometry data.

FVC % was calculated by equation:

FVC % = measured FVC / reference value for FVC x 100

Similarly, FEV<sub>1</sub> % was calculated as:

 $FEV_1 \%$  = measured  $FEV_1$  / reference value for  $FEV_1 x 100$ 

Baseline characteristics and lung volumes between genders were tested by independent sample t-test. Mean values of lung volumes in BMI categories were analyzed by One-way Analysis of Variance (ANOVA). Post-hoc Tukey's test was used to compare pair-wise significance of lung volumes in BMI category. Pearson's product moment correlation was used to assess linear correlations between anthropometric variables and long volumes. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 17.0 (SPSS, Inc., Chicago, IL). P-value  $\leq$  0.05 considered as significant.

#### RESULTS

The baseline characteristics of all subjects had a normal distribution. Mean ( $\pm$ SD) age of our subjects was 40.65 ( $\pm$ 7.86) years. Mean height and weight of our subjects

was 168.63 (±6.85) cm and 75.68 (±13.83) kg respectively. All subjects had a mean BMI of 26.53 (±4.14) kg/m<sup>2</sup>. The sample included 79 normal (BMI 18.5 - 24.9 kg/m<sup>2</sup>), 102 overweight (BMI 25 - 29.9 kg/m<sup>2</sup>) and 45 obese (BMI  $\geq$  30 kg/m<sup>2</sup>) subjects.

A comparison of mean values of FVC% between male (94.24  $\pm$  11.82) and female (95.68  $\pm$  13.65) participants was not significant (p = 0.52). Similarly, FEV<sub>1</sub>% of males (93.25  $\pm$  12.16) did not significantly differ from that of females (95.34  $\pm$  13.93). However, mean  $\pm$  SD FEV<sub>1</sub>:FVC of males (81.86  $\pm$  5.47) was significantly lower (p < 0.0001) than those of females (85.47  $\pm$  5.41). Characteristics of participants by gender are shown in Table I.

BMI categories had significant effect on lung volumes. A trend of decreasing mean FVC% and FEV<sub>1</sub>% with increasing BMI in normal, overweight and obese existed in this sample, as shown in Table II. Obese subjects had significantly lower FVC% (89.57  $\pm$  10.96) than those of normal subjects (97.97  $\pm$  10.92). FEV<sub>1</sub>% of obese subjects (89.39  $\pm$  12.65) was also significantly lower than those of normal subjects (96.85  $\pm$  11.11). However, mean FVC% and FEV<sub>1</sub>% of normal subjects was not

Table I: Comparison of characteristics of study participants by gender.

Variables	Males (n=180)	Females (n=45)	p-value
Age (years)	40.93 ± 8.04	39.06 ± 6.61	0.200
Height (cm)	170.41 ± 5.50	158.56 ± 4.87	< 0.0001*
Weight (kg)	78.01 ± 12.98	62.50 ± 10.86	< 0.0001*
BMI (kg/m <sup>2</sup> )	26.83 ± 4.12	24.82 ± 3.87	0.009*
FVC (%)	94.24 ± 11.82	95.68 ± 13.65	0.523
FEV <sub>1</sub> (%)	93.25 ± 12.16	95.34 ± 13.93	0.368
FEV <sub>1</sub> :FVC	81.86 ± 5.47	85.47 ± 5.41	< 0.0001*

Data presented as Mean ± SD; \*Significant at p < 0.05 level

 Table II: Comparison of characteristics of participants by BMI category.

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Variable	Normal	Overweight	Obese	p-value
	(n=78)	(n=102)	(n=45)	
Age (years)	38.81±7.72	41.30±8.0	42.40±7.27	0.026*
Height (cm)	167.10±7.42	169.61±6.44	169.09±6.38	0.044*
Weight (kg)	62.18±7.01	78.45±6.86	93.09±11.30	< 0.0001*
BMI (kg/m <sup>2</sup> )	22.25±1.92	27.24±1.49	32.42±2.55	< 0.0001*
FVC (%)	97.97 ± 10.92	93.89 ± 12.68	89.57 ± 10.96¶	0.001*
FEV1 (%)	96.85 ± 11.11	92.86 ± 12.74	89.39 ± 12.65¶	0.004*
FEV <sub>1</sub> :FVC	82.86 ± 4.83	81.99 ± 5.90	82.52 ± 6.19	0.578

\* Significant at p < 0.05 level; ¶ Significantly lower than normal subjects (post-hoc).

 
 Table III: Pearson correlation coefficient between BMI and lung volumes by gender.

Gender	FVC (%)	FEV <sub>1</sub> (%)	FEV <sub>1</sub> :FVC (%)
Male (n=180)			
Pearson's r	-0.302	-0.264	0.002
p-value	< 0.0001*	< 0.0001*	.977
Female (n=45)			
Pearson's r	-0.395	-0.391	0.068
p-value	0.021*	0.022*	0.704

\* Significant at p < 0.05 level

significantly different from overweight subjects. Similarly, difference of mean FVC% and FEV<sub>1</sub>% between overweight and obese was also not statistically significant. BMI categories had no effect on FEV<sub>1</sub>:FVC.

Pearson's product moment correlation between lung volumes and BMI was analyzed separately in BMI



Figure 1: Effect of increasing BMI on FVC% split by BMI categories showing trend line for each category.

The Pearson correlation coefficients split by BMI category in above figure are: Normal: r = - 0.05, p = 0.66; Overweight: r = - 0.19, p = 0.47; Obese: r = - 0.48, p = 0.001\*; \* Significant at p < 0.05 level.



Figure 2: Effect of increasing BMI on  $\mathsf{FEV}_1\%$  split by BMI categories showing trend line for each category.

The Pearson correlation coefficients split by BMI category in above figure are: Normal: r = - 0.09, p = 0.40; Overweight: r = - 0.10, p = 0.31; Obese: r = - 0.48, p = <0.0001\*; \* Significant at p < 0.05 level. categories. Linear correlations between FVC% and BMI was significantly negative in our overweight (r = -0.197; p = 0.047) and obese subjects (r = - 0.488; p = 0.001). Correlation between FVC% and BMI in normal subjects was not statistically significant. Correlations between FVC% and BMI split by BMI categories are shown in Figure 1. FEV<sub>1</sub>% had negative correlation with BMI in obese (r = - 0.510; p < 0.0001). Correlation between BMI and FEV<sub>1</sub>% was not statistically significant in normal and overweight subjects. Correlations between FEV<sub>1</sub>% and BMI split by BMI categories are shown in Figure 2. No significant correlation was observed between FEV<sub>1</sub>;FVC and BMI.

Correlation between lung volumes and BMI was analyzed separately in both genders as presented in Table III. Lung volumes including FVC% and FEV<sub>1</sub>% had significant negative correlation with BMI in both males and females. This correlation was stronger in males than females. Correlation between FEV<sub>1</sub>:FVC and BMI was insignificant.

## DISCUSSION

This study reports the findings of association between obesity and lung volumes in a sample of adult Pakistanis who comprised of office workers in the city of Lahore. It was found that gender had no effect on mean values of FVC% and FEV<sub>1</sub>%. This is in contrast to other researchers who have reported significantly higher values of baseline pulmonary function in males.<sup>16,17</sup> This gender difference reported by others is likely to be attributed to the fact that men tend to have bigger lungs for same height when compared with females. Muscularity in men is another contributing factor to higher values of pulmonary function among men.<sup>12</sup> No gender differences of baseline pulmonary function among these participants may be due to fewer females compared to males in our sample (male to female 4:1); and analysis of pulmonary function variables as percentage of predicted value. This is in contrast to some of the researchers who have reported measured volumes in liters, which tend to be higher in males compared with females.<sup>15</sup>

It is important to note that lung volumes reported as percentage of predicted value are a linear variable related to lung compliance. The proposed added advantage of using percent predicted values of lung function is a possible adjustment for the effects of age and gender on measured lung volumes in litres, which are affected by an individual's gender and age.<sup>12</sup> Observing the same phenomenon, Osch-Balcom *et al.* reported that raw values of FVC and FEV<sub>1</sub> were higher in men but after adjustment for age, percent predicted values were higher among women.<sup>18</sup> FEV<sub>1</sub>:FVC in this study showed significant gender difference as it was presented as measured values of FVC and FEV<sub>1</sub> in liters which depend upon age and gender as highlighted above.

In this study, obese participants (BMI > 30 kg/m<sup>2</sup>) had significantly lower values of FVC% and FEV<sub>1</sub>% as compared to normal (BMI < 25 kg/m<sup>2</sup>). These findings are consistent with those of some investigators who have shown that lung volumes are significantly lower among subjects in higher BMI groups.<sup>6,19</sup> The differences of pulmonary function among BMI categories in this study differ from some others. Costa *et al.* reported no significant difference of FVC%, FEV<sub>1</sub>% and FEV<sub>1</sub>:FVC among obese (mean BMI 41.1 kg/m<sup>2</sup>) and non-obese (mean BMI 21.9 kg/m<sup>2</sup>) females in Brazil.<sup>20</sup>

Significant negative linear correlation between BMI and FVC% in the overweight and the obese was found in this sample. Negative linear correlation between FEV<sub>1</sub>% and BMI was significant in the obese only. Studying the same association, Al-Badr et al. reported significant inverse association between BMI and both FVC% and FEV<sub>1</sub>% in obese subjects only.<sup>19</sup> The results are consistent with results reported by Steele et al. from proactive trial in British adults having family history of T2DM as well as by Morsi who studied Saudi adults with varying degree of asthma and reported inverse correlation of BMI with FVC and FEV<sub>1</sub>.8,21 The present results are different from some other researchers working on other ethnic populations. Chen et al. detected positive association of BMI with FVC and FEV1 in normal weight Canadians but negative association among overweight and obese subjects.<sup>22</sup> Rasslan et al. found no significant correlation between pulmonary function and BMI among a sample of Brazilians.23 Moreover, Koziel et al. reported positive association of BMI with lung function among both males and females in Poland.<sup>24</sup> Correlation of BMI with pulmonary function is very diverse and complicated as reported by various researchers across various populations. Thus, exact nature of difference of pulmonary functions among subjects in different BMI groups and gender in different ethnic groups remains difficult to interpret.

Proposed mechanisms for link between obesity and pulmonary dysfunction include changes in wide ranging mechanisms including respiratory mechanics, respiratory muscle function, respiratory resistance, lung volumes, work of breathing and gaseous exchange. Despite our limitations, which are inevitable in a cross-sectional study of modest sample size, we were able to demonstrate strong and highly significant relationship between obesity and lung volumes.

## CONCLUSION

Increasing BMI is associated with decreased lung volumes in a sample of office workers of either gender. Larger epidemiological studies in future may help further elucidate these relationships for Pakistani population for formulating public health policy and action.

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