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RESEARCH ARTICLE

EFFECT OF BODY MASS INDEX ON LUNG VOLUMES

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ABSTRACT

Obesity is becoming a major public health problem with severe health and economic implications. The aim of this study is to find the influence of obesity on lung function by comparing the lung volumes in normal weight, overweight and obese subjects by using Body Mass Index - as a measure of overall adiposity and to find whether the effect of BMI on lung volumes varies between obese males and females. Pulmonary function parameters including FVC, FEV_1, PEFR, ERV, FEV_1/ FVC ratio & MVV were measured using computerized spirometer in 103 subjects aged between 20 and 45 years recruited from the vicinity of Thanjavur Medical College. Of these 45 had normal BMI, 29 were overweight and 29 were obese. 54 were males and 49 were females. The present study found significant negative association of BMI with the lung volumes in both obese subjects and in overweight subjects. It was also found that BMI influences pulmonary function to different extent in males and females

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INTRODUCTION

Obesity is fast assuming epidemic proportions. Obesity has a clear potential to have a direct effect on respiratory well being. Pulmonary Function Tests have become a valuable tool in the armamentarium of investigations available with the physician as a guide in the diagnosis and treatment of respiratory pathologies. Current lung function prediction equations utilize only general measures of body size like height, age, race and gender (Collins, Lynell *et al*., 1995). They do not take weight into account for most of the parameters. If abdominal or upper body deposition of fat decreases diaphragmatic excursion due to increased abdominal adiposity or increased weight on the chest wall, measured lung volumes might be smaller than predicted using current predictive equations. Therefore it is important to understand the relationship between BMI which is recognized by the WHO as the most useful epidemiological measure of obesity and lung volumes. According to WHO's Global Infobase statistics (WHO-Global Database, 2010) for the year 2010, in India, 20.1 % males and 18.1% females above the age of 15 years have a BMI $\geq$ 25 kg/m^2. 1.7 % of males and 2% of females above the age of 15 are classified as obese [BMI $\geq$ 30 kg/m^2] according to the same report.

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Obesity causes respiratory embarrassment by several mechanisms. Even uncomplicated simple obesity exerts effects on pulmonary gas exchange, oxygenation of the blood, and the work of breathing and it has modest effects on ventilatory drive and the pattern of breathing. Richard L Jones (Richard L Jones *et al*., 2006) and associates showed that ERV decreased exponentially with increasing BMI. Sahebjami and associates (Sahebjami *et al*., 1996) studied 63 obese males without significant airway obstruction and they found low MVV in 42 of the subjects. Rubinstein (Rubinstein *et al*., 1990) in a study comparing lung volumes in 103 obese, lifelong non-smokers without cardiopulmonary diseases with 190 healthy non-obese non-smokers, found significantly reduced FVC and FEV_1 in the obese group. Anuradha R Joshi (Anuradha R Joshi *et al*., 2008) who measured lung function in overweight and normal weight student volunteers found significant reduction of FEV_1 in the overweight subjects compared to normal weight subjects. These physiological changes are more pronounced during recumbency in obese subjects as compared with normal weight subjects, because of the increased gravitational effects of the large abdomen.

Aims and Objectives

- To find the influence of Obesity on Lung function by comparing the Lung Volumes in Normal weight, Overweight and Obese subjects by using Body Mass Index - as a measure of Overall Adiposity and

- To find whether the effect of BMI on lung volumes varies between obese males and females.

MATERIALS AND METHODS

The study was done in the Research Laboratory, Department of Physiology, Thanjavur Medical College. Participants both males & females were randomly recruited from the general population residing around Thanjavur Medical College, aged between 20 and 45 years. 103 healthy volunteers participated in the study [54 males and 49 females]. The study protocol was approved by the Institutional Ethics Committee of Thanjavur Medical College. Written informed consent was obtained. Protocol described by Helsinki Declaration was followed (World Medical Association Declaration of Helsinki, 2008)

Demographic information, family history, medical history with emphasis on symptoms suggestive of chest diseases, smoking history, drug history and lifestyle history were obtained by interview using a questionnaire. Thorough clinical examination was done with emphasis on chest examination. All the recordings i.e. anthropometric measurements and recording of Pulmonary Function Tests were conducted in one sitting on the same day. Subjects with Hypertension, Ischaemic Heart Disease, Diabetes Mellitus, Lung disease, Neuromuscular abnormalities including Kyphoscoliosis, Smokers and Subjects with BMI less than 18.5 kg/m^2 were excluded from the study.

All anthropometric measurements were obtained with the subjects wearing lightweight clothes without shoes. They were recorded in the morning two hours after light breakfast with empty bladder. Beam balance was used to measure standing weight. Weight was measured to the nearest 0.1 kg. Height was recorded using a stadiometer with the subject standing erect with heels together with back as straight as possible with the head positioned so that the top of the external auditory meatus is at level with the inferior margin of the bony orbit [Frankfurt's plane] (Parikh *et al*., 2009). Body Mass Index [BMI] was calculated from the measured height and weight using Quetelet's Index (Park & Park) (Parikh *et al*., 2009)

$$BMI = \frac{\text{Weight in kg}}{\text{Height in m}^2}$$

Based on BMI, the study subjects were classified into three groups as shown in Table 1

Table 1. BMI groups

Group Name	Category	BMI (Kg/m^2)
I	Normal weight	18.50 to 24.99
II	Overweight	25.00 to 29.99
III	Obese	≥ 30

Pulmonary function tests were done using Computerized Spirometer [Spiro Excel – Digital Spirometer - Medicaid Systems]. The tests were carried in the research laboratory in a quiet setting in sitting posture after 10 to 15 minutes of rest. A nose clip was applied and the subjects were instructed to breathe into the disposable mouth piece connected to the system, with lips sealed around the mouth piece. Each maneuver was explained and demonstrated to the subjects.

The directly evaluated parameters were lung volumes, capacities and flows through the procedures of Slow Vital Capacity [SVC], Forced Vital Capacity [FVC], and Maximum Voluntary Ventilation [MVV] performed at least three times each, according to the standards of American Thoracic Society [ATS] and European Respiratory Society [ERS]. Best of the acceptable, reproducible recordings was selected (Miller *et al*., 2006). The recorded parameters were compared with the in-built pulmonary function norms for the given population. Results were expressed as absolute values and as percentage of the predicted values. By means of the FVC procedure, the following variables were obtained.

- Forced Vital Capacity [FVC]
- Forced Expiratory Volume in one second [FEV_1]
- FEV_1/ FVC ratio
- Peak Expiratory Flow Rate [PEFR]
- Forced Expiratory Flow [$FEF_{25\%}$]
- By means of the SVC procedure, following variable was obtained.
- Expiratory Reserve Volume [ERV]

The MVV was expressed in Litres/min and as percentage of the predicted value.

For statistical analysis of recorded data, software package SPSS (Statistical Package for Social Sciences) Version 10 was used. Descriptive analysis was done. Mean values including Standard deviation were computed for all relevant variables and Independent Student's T Test was applied to compare the means of different variable and Statistical significance was noted. Pearson's Correlation test was used to assess relationship between physical measurements and statistical significance was recorded. The non- zero values of 'r' between -1 to 0 indicate negative correlation. P value < 0.05 was taken as significant for all the tests (Mahajan's BioStatistics). Trends of respiratory parameters were analysed by stratifying data according to BMI categories based on WHO criteria for obesity.

The different BMI categories were compared as under:

Normal WeightVsObese
Normal WeightVsOverweight
OverweightVsObese

Results were analysed to assess the effects of BMI on lung volumes. Analysis was performed for the whole cohort and also separately for men and women.

RESULTS

103 subjects without co-morbidities participated in the study. The BMI groups were stratified based on gender and the frequency distribution of the various groups is shown in Table 2. Mean and Standard Deviation was calculated and recorded for all the relevant parameters as shown in Table 3.

Table 2. BMI groups-Frequency distribution

			Sex		Total
			Male	Female	
BMI Groups	Normal	Count	25	20	45
		% Within Sex	46.3%	40.8%	43.7%
	Overweight	Count	17	12	29
		% Within Sex	31.5%	24.5%	28.2%
	Obese	Count	12	17	29
		% Within Sex	22.2%	34.7%	28.2%
Total		Count	54	49	103
		% Within Sex	100.0%	100.0%	100.0%

P=0.360 [Not Significant]

Figure 1 compares the mean values of different recorded spirometric variables between the three BMI groups. Tables 4, 5 and 6 show the P value calculated for testing equality of means for the various spirometric variables between the various BMI groups using Independent Student's t test.

The Mean FEV_1 % Predicted, FVC % Predicted and PEFR % Predicted were significantly lower [P < 0.05] in the Overweight BMI Group compared to the Normal BMI group while FEV_1 /FVC % Predicted, $FEF_{25\%}$ % Predicted, MVV % Predicted and ERV (L) did not show significant difference of Means between the Normal and Overweight BMI groups.

Table 3. Mean & Standard Deviation of recorded parameters in BMI groups

BMI Groups	SEX		FEV1 % Predicted	FVC % Predicted	FEV1/FVC % Predicted	PEFR % Predicted	FEF25% % Predicted	MVV % Predicted	ERV(L)
Normal	Male	Mean	91.1	88.488	107.968	101.804	116.332	74.248	1.5584
		SD	11.3679	10.2214	8.5533	14.7102	18.6938	21.4361	0.7443
	Female	Mean	95.115	91.92	108.275	98.12	106.72	64.25	1.3475
		SD	12.2777	10.6365	6.7091	17.5797	17.2307	16.5016	0.4901
	Total	Mean	92.8844	90.0133	108.1044	100.1667	112.06	69.8044	1.4647
		SD	11.8175	10.4315	7.705	15.9659	18.4973	19.836	0.6458
Overweight	Male	Mean	88.4118	84.5882	109.1176	92.4118	106.1765	65.3529	1.3888
		SD	9.042	6.5389	8.5285	13.643	13.244	28.3482	0.8177
	Female	Mean	86.2917	84.9833	107.2667	90.9583	100.7	63.9167	1.0075
		SD	10.7227	8.8357	5.2213	19.9331	20.5155	24.1979	0.6395
	Total	Mean	87.5345	84.7517	108.3517	91.8103	103.9103	64.7586	1.231
		SD	9.6445	7.4258	7.2893	16.2168	16.5262	26.2633	0.7611
Obese	Male	Mean	81.75	77.5833	110.5	84.5	94.75	58.925	1.1992
		SD	14.4482	11.0327	10.2292	16.5941	15.858	28.3031	0.7312
	Female	Mean	78.6706	75.6176	109.8118	79.7588	84.9529	37.0125	0.9971
		SD	20.5923	16.1047	13.4843	22.6821	22.8443	14.296	0.7922
	Total	Mean	79.9448	76.431	110.0966	81.7207	89.0069	46.4036	1.0807
		SD	18.0749	14.0355	12.0469	20.1944	20.5211	23.7033	0.7609

Table 4. Comparison between Normal and Overweight BMI groups as regards parameters of pulmonary function

[t- test for Equality of Means between Normal and Overweight BMI groups]

	df	P value Sig (2 tailed)	Mean Difference	SE Difference	95 % Confidence Interval of the Difference	
					Lower	Upper
FEV_1 % Predicted	72	0.045*	5.35	2.625	0.1171	10.5828
FVC % Predicted	72	0.021*	5.2616	2.2331	0.81	9.7132
FEV_1 /FVC % Predicted	72	0.891	-0.2473	1.7969	-3.8294	3.3348
PEFR % Predicted	72	0.032*	8.3563	3.8253	0.7308	15.9819
$FEF_{25\%}$ % Predicted	72	0.058	8.1497	4.2284	-0.2795	16.5788
MVV % Predicted	72	0.351	5.0458	5.3708	-5.6606	15.7523
ERV (L)	72	0.161	0.2336	0.165	-9.53E-02	0.5626

*P value < 0.05 was taken as statistically significant.

Table 5. Comparison between Normal and Obese BMI groups as regards parameters of pulmonary function

[t- test for Equality of Means between Normal and Obese BMI groups]

	df	P value Sig(2 tailed)	Mean Difference	SE Difference	95 % Confidence Interval of the Difference	
					Lower	Upper
FEV_1 % Predicted	72	< 0.0005*	12.9396	3.4704	6.0215	19.8578
FVC % Predicted	72	< 0.0005*	13.5823	2.8487	7.9036	19.261
FEV_1 /FVC % Predicted	72	0.388	-1.9921	2.2929	-6.563	2.5788
PEFR % Predicted	72	< 0.0005*	18.446	4.2221	10.0293	26.8626
$FEF_{25\%}$ % Predicted	72	< 0.0005*	23.0531	4.5982	13.8869	32.2193
MVV % Predicted	72	< 0.0005*	23.4009	5.1484	13.1353	33.6665
ERV (L)	72	0.023*	0.384	0.165	5.51E-02	0.7129

*P value < 0.05 was taken as statistically significant.

FEV_1 % Predicted, FVC % Predicted, PEFR % Predicted, $FEF_{25\%}$

Table 6. Comparison between Overweight and Obese BMI groups as regards parameters of pulmonary function

[t- test for Equality of Means between Overweight and Obese BMI groups]

	Df	P value Sig (2 tailed)	Mean Difference	SE Difference	95 % Confidence Interval of the Difference	
					Lower	Upper
FEV_1 % Predicted	56	0.051	7.5897	3.8044	-3.14E-02	15.2107
FVC % Predicted	56	0.007*	8.3207	2.9486	2.4139	14.2275
FEV_1 /FVC % Predicted	56	0.507	-1.7448	2.6147	-6.9827	3.493
PEFR % Predicted	56	0.04*	10.0897	4.8095	0.4551	19.7242
$FEF_{25\%}$ % Predicted	56	0.004*	14.9034	4.8927	5.1021	24.7048
MVV % Predicted	56	0.008*	18.355	6.6341	5.06	31.6501
ERV (L)	56	0.455	0.1503	0.1998	-O.2500	0.5507

*P value < 0.05 was taken as statistically significant.

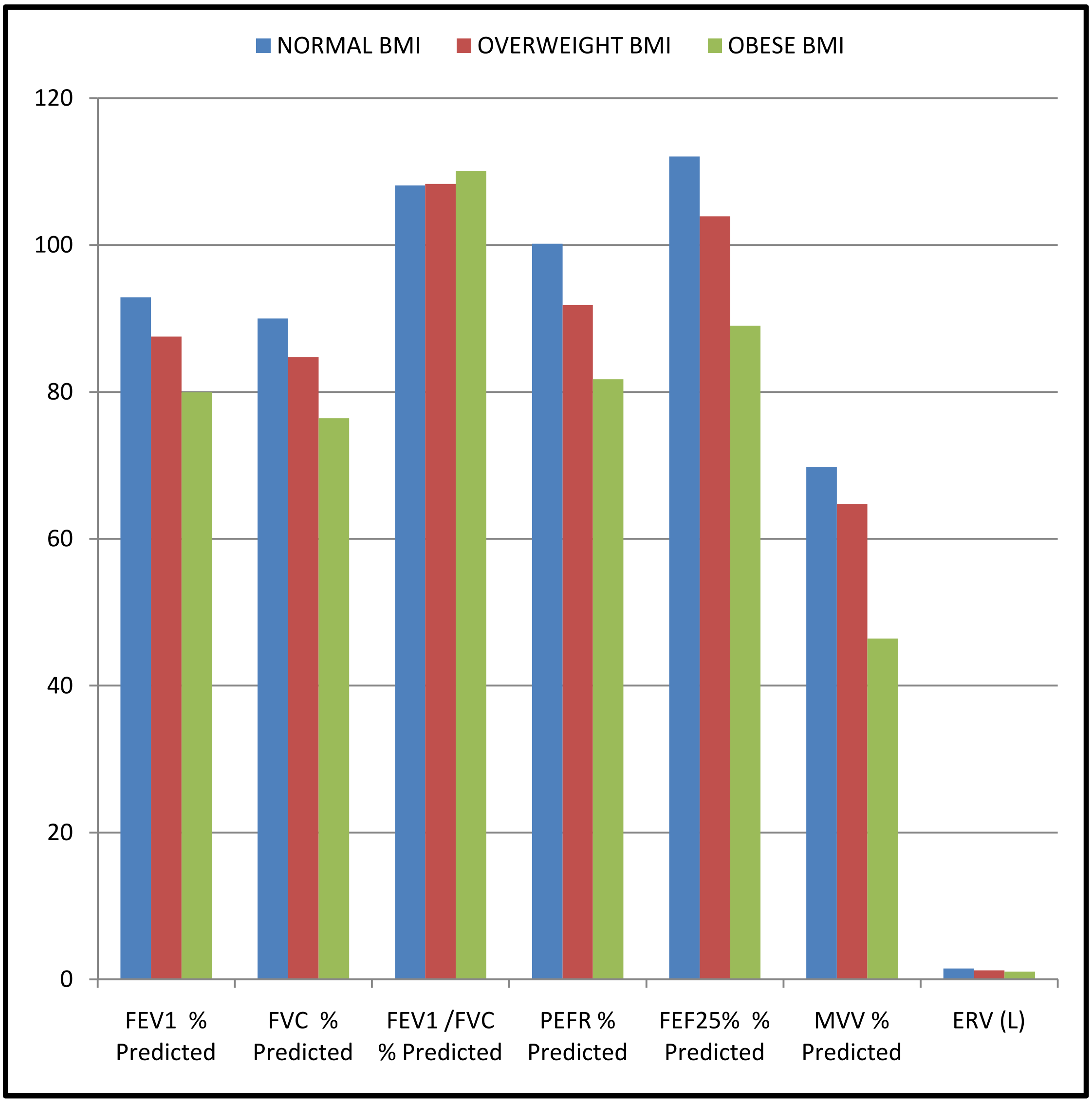

Figure 1. Comparison between various BMI groups as regards parameters of pulmonary function

Table 7. Correlation between BMI and the parameters of pulmonary function

	BMI (Correlation-Whole group)		BMI(Correlation-Males)		BMI(Correlation-Females)	
	Pearson Correlation	P value -Sig. (2 Tailed)	Pearson Correlation	P value -Sig. (2 Tailed)	Pearson Correlation	P value -Sig. (2 Tailed)
FEV_1 % Predicted	-0.393	< 0.0005*	-0.256	0.062	-0.486	< 0.0005*
FVC % Predicted	-0.488	< 0.0005*	-0.343	0.011*	-0.592	< 0.0005*
FEV_1 /FVC % Predicted	0.108	0.278	0.068	0.626	0.15	0.304
PEFR % Predicted	-0.374	< 0.0005*	-0.313	0.021*	-0.402	0.004*
$FEF_{25\%}$ % Predicted	-0.412	< 0.0005*	-0.316	0.02*	-0.465	0.001*
MVV % Predicted	-0.331	0.001*	-0.186	0.179	-0.493	< 0.0005*
ERV (L)	-0.227	0.021*	-0.232	0.091	-0.192	0.187

*P value < 0.05 was taken as statistically significant.

% Predicted, MVV % Predicted and ERV (L) were significantly decreased in the Obese BMI group, when compared to the Normal BMI group [P value < 0.05].

FEV_1 /FVC % Predicted was higher in the Obese BMI group compared to the Normal BMI group, but the difference was not statistically significant as seen in Table 6.

When the Overweight and Obese BMI groups were compared, FVC % Predicted, PEFR % Predicted , $FEF_{25\%}$ % Predicted and MVV % Predicted were significantly lower in the Obese group [P value < 0.05]. The other parameters like FEV_1 %Predicted, FEV_1 /FVC % Predicted, ERV (L) did not show significant difference of means.

As shown in Table 7, when Correlation study was done ignoring gender difference, all recorded variables except FEV_1/FVC % Predicted showed significant negative correlation with BMI [P < 0.05]. FEV_1 /FVC % Predicted showed positive correlation but it was not significant. When the correlation tests were done separately in male and female subjects, the results were different. In males, FVC % Predicted, PEFR %Predicted , $FEF_{25\%}$ % Predicted showed significant negative correlation with BMI, while in females, except FEV_1 /FVC % Predicted and ERV (L) all the other parameters showed significant negative correlation with BMI.

DISCUSSION

The effect of obesity on pulmonary function varies considerably between individuals, ranging from trivial to profound impairment but generally increases in severity with the BMI. In the present study, Obese BMI group showed lower values of FEV_1 and FVC when compared to the Normal weight BMI group and the difference was statistically significant. Low FVC and FEV_1 indicate a restrictive type of defect. The results of our study agreed with that of Rubinstein *et al* (Rubinstein *et al*., ?). They found significantly reduced FVC and FEV_1 in the obese group. Ross Lazarus and associates (Ross Lazarus *et al*., ?) showed that BMI is negatively associated with FVC in Normative Aging Study similar to our study results.

Even moderate amount of increase in BMI can cause changes in lung volumes. Hence in the present study, the lung function parameters of the Overweight BMI group were compared with that of the Normal Weight BMI group. FEV_1 and FVC were significantly lower in the overweight group. This is in comparison with the report of Anuradha R Joshi *et al.* (Anuradha R Joshi *et al*., 2008) who measured lung function in overweight and normal weight student volunteers and found significant reduction of FEV_1 in the overweight subjects compared to normal weight subjects.

This study showed significant negative correlation of BMI with FVC and FEV_1 in females, but not in males. This may be explained by the fact that obesity aside, women have less respiratory muscle strength and therefore produce lower dynamic compression. The hyperventilation caused by the effect of progesterone on the bulbar respiratory neurons, airways and diaphragm may also explain these alterations. Mean FEV_1/ FVC Ratio was found to be higher in the overweight and obese groups compared to the normal weight group. BMI showed positive correlation with FEV_1/ FVC Ratio but it was not significant. Similar to the present study, Anuradha R Joshi (Anuradha R Joshi *et al*., 2008) have found normal FEV_1/ FVC Ratio in overweight individuals. Ross Lazarus l (Ross Lazarus *et al*., 1997) also found similar positive association of BMI with FEV_1/ FVC Ratio in all age groups in their Normative Aging Study. Heather M Oches (Heather M Oches *et al*., 2006) have also shown significant positive association between BMI and FEV_1/ FVC Ratio which conforms to the present study results as regards FEV_1/ FVC Ratio.

Both overweight and obese BMI groups had lower PEFR compared to the normal weight group. The correlation between BMI and PEFR was statistically significant in both males and females. $FEF_{25\%}$ showed significant negative correlation with BMI in both males and females. Obese BMI group showed significant reduction of MVV when compared to overweight and normal weight BMI groups. This significant difference was maintained even when the groups were analysed based on gender. ERV was significantly decreased in the Obese BMI group, when compared to the Normal weight BMI group when analysed without considering gender. ERV was found to decrease exponentially with increasing BMI, and the greatest effect were on subjects with BMI >30 Kg/m^2. Costa D and associates Costa *et al*., 2008) have found reduced ERV in obese female subjects.

Conclusion

The present study found significant negative association of BMI with the lung volumes. This effect was seen not only in obese subjects but also in overweight subjects. This strengthens the hypothesis of this study that BMI influence lung volumes. All the above changes were seen in clinically normal subjects without co-morbidities. It was also found that BMI influence pulmonary function to different extents in males and females. Hence the routine calculation of BMI will help the interpreting physician to take into account the effect of overall adiposity on Lung Volumes. Larger studies done in the population will help in modifying Prediction Equations of Pulmonary Function tests for males and females to prevent unwarranted costly investigations in clinically normal obese subjects. Also subjects can be motivated to achieve and maintain ideal body weight as the present study has proven that High BMI impairs lung function.

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