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A Study of Correlation Between BMI and Pulmonary Function Test

Ravi Kamble[1*], Sanjay Gaikwad[2]
[1]*Junior Resident, Department of Respiratory Medicine, Byramjee Jeejeebhoy Government Medical College, Pune, India*
[2]*Professor & Head of the Department, Department of Pulmonary Medicine, Byramjee Jeejeebhoy Government Medical College, Pune, India*

***Abstract*: Overweight and obesity are significant health issues in both developed and developing nations. As per the National Family Health Survey data, 12.1% of males and 16% of females in India are overweight or obese. The primary cause of this problem is an imbalance between calorie intake and calorie expenditure. While studies have explored the effect of obesity on pulmonary function tests (PFT), little attention has been given to the role of body fat distribution. While several studies have reported on PFT in obesity, only a few studies have been conducted on underweight individuals, and there are very few comparative studies of PFT that include all three categories of BMI. Hence, the current study aimed to evaluate the change in pulmonary functions in the three categories of BMI – normal, underweight, and overweight.**

***Keywords*: Body Mass Index (BMI), Pulmonary function test, FEV1, FEV1/FVC, PEF, overweight, underweight.**

1. Introduction

Respiratory illnesses constitute a significant source of morbidity and premature mortality across the globe, primarily because lungs are frequently affected by multi-system disorders. Pulmonary function tests are utilized to assist with diagnosis, evaluate functional impairment, and monitor the progression or response to treatment of respiratory ailments. Numerous factors contribute to variations in pulmonary function in healthy individuals, including ethnicity, physical activity, environmental factors, altitude, smoking habits, age, height, gender, and socioeconomic status.

As the Indian population undergoes a shift in their nutritional habits, the prevalence of adult non-communicable diseases is expected to rise. This is being fueled by urbanization and globalization, resulting in a "dual burden of disease" where both underweight and overweight individuals are affected. Body Mass Index (BMI) is a widely accepted indicator of nutritional status and general health screening. The prevalence of underweight and overweight individuals in India is high, with approximately 43-48% of 15-45-year-olds facing the dual burden3. While underweight is still prevalent, the prevalence of overweight and obesity is increasing at an alarming rate, and it is now the sixth most important risk factor contributing to the global disease burden. Overweight and obesity are associated with an increased burden of various health conditions, including diabetes, hypertension, cardiovascular disease, cancers, and premature mortality. Obesity also has a negative impact on pulmonary function, causing alterations in respiratory mechanics, decreased respiratory muscle strength, lower pulmonary gas exchange, decreased control of breathing, and limitations in pulmonary function tests. Studies have shown that undernutrition can also have adverse effects on respiratory muscle mass, resulting in respiratory muscle atrophy and reduced pulmonary function. While several studies have been conducted on the impact of obesity on pulmonary function, fewer studies have been conducted on underweight individuals, and comparative studies across all three BMI categories are limited. In this study, pulmonary function tests are analyzed in individuals across the three categories of BMI - normal, underweight, and overweight.

2. Review of Literature

The act of breathing is necessary for survival and any changes in lung function can affect one's daily activities and quality of life. The respiratory system structures must work together in balance to ensure respiratory homeostasis, allowing for proper ventilation and gas diffusion through the alveolar-capillary barrier. Pulmonary function tests are often used to evaluate respiratory status, diagnose pulmonary diseases, and as part of routine health examinations in fields such as respiratory, occupational, and sports medicine, as well as public health screenings. The primary function of pulmonary function tests is to measure the uptake of oxygen from inspired air and the release of carbon dioxide in expired air, thereby maintaining the normal range of oxygen and carbon dioxide levels in arterial blood. Spirometry is a physiological test that measures an individual's ability to inhale and exhale a specific volume of air over time. This test assesses the integrated mechanical function of the lung, chest wall, and respiratory muscles, and evaluates various aspects of pulmonary function such as ventilation, perfusion, and diffusion. Measurable pulmonary parameters, including tidal volume, inspiratory reserve volume, expiratory reserve volume, inspiratory capacity, vital capacity, forced expiratory volume in one second, forced vital capacity, and forced expiratory flow (FEF25-75%), can be determined using spirometry.

Tiffeneau and Pinelli introduced the current format for spirometric measurements in 1947, which included FEV1, IVC,

*Corresponding author: ravi.bk3@outlook.com

and FVC as primary diagnostic indicators in clinical medicine. The American Thoracic Society formed a committee to establish norms for spirometric techniques during the snowbird workshop in 1979, which were subsequently updated in 1987 and 2001. The European Respiratory Society (ERS) also developed their own guidelines for spirometry, which included absolute lung volume that was not covered by the ATS guidelines. The ERS guidelines were first established in 1993 and updated in 1994. Currently, spirometry is commonly used as a screening test to rule out respiratory illnesses.

Factors affecting the lung functions:

Pulmonary functions are generally determined by

1. Airway resistance,
2. Compliance of the lung & thoracic cavity,
3. Elastic recoil of the lung
4. Respiratory muscle strength.

Spirometric lung function parameters can be affected by many sorts of variations such as,

1. Technical variations which include instrument & procedural variations, observer bias, & individual variation & their interaction.
2. Biological variations which include intra-& inter – individual variations among populations.
3. Clinical variations which include variations caused by dysfunction or disease.

The most important determinant of inter individual variability in lung functions are,

Race or ethnic origin is an important determinant of inter individual variability in lung functions. Differences in lung volumes and capacities have been observed among various racial and ethnic groups, including Whites, Blacks, Hispanics, Native Americans, Asians, Latin Americans, Indians, and South Africans. These differences are likely due to variations in body size, chest shape, and genetic factors.

Age is an important determinant of inter individual variability in lung functions, with a reduction in lung volumes and capacities as individuals get older. This is due to several factors such as decreased elasticity of lung tissue, decreased strength of respiratory muscles, and changes in the thorax that occur with aging. These changes can result in decreased lung function and increased risk of respiratory diseases in older individuals. The differences in pulmonary function between males and females can be attributed to factors such as differences in lung size and respiratory muscle strength, as well as differences in fat distribution. Additionally, hormonal factors may also play a role.

Weight can have various effects on pulmonary function tests, including impairment, small airway dysfunction, alterations in respiratory mechanics, decreased chest wall and lung compliance, decreased respiratory muscle strength and endurance, decreased pulmonary gas exchange, lower control of breathing, and limitations in exercise capacity. Shorter individuals also tend to have smaller PFT results compared to taller individuals of the same age, and PFT has a highly positive correlation with height in both sitting and standing postures for both sexes.

3. Materials and Methodology

During the study, participants were instructed to wear lightweight clothing. Height was measured in an upright position using a stadiometer, and recorded to the nearest centimetre. Weight was measured using a standard weighing machine with no shoes, and recorded to the nearest kilogram. Body mass index (BMI) was calculated using Quetelet's Index, which is the ratio of weight in kilograms to height in meters squared.

$$BMI = Wt\ in\ Kg / (Ht\ In\ M)^2$$

Participants were then categorized into three groups based on the World Health Organization's BMI classification system:

Underweight: BMI < 18.5
Normal: BMI 18.5 to 24.9
Overweight: BMI > 25.0
Pre-obese: BMI 25.0 to 29.9
Obese: BMI > 30.0

The evaluation of pulmonary function involved measuring lung volumes using a Computerized Spirometer while the subjects were seated in a calm environment. The procedure was demonstrated to the participants before the measurements were taken. The Computerized Spirometer used for the pulmonary function test was the "COSMED" model, which provides predicted values based on ERS 93 standards. The measurement process adhered to the guidelines set by the American Thoracic Society, and each subject performed three satisfactory efforts.

The following parameters were recorded: FVC (forced vital capacity), FEV1 (forced expiratory volume at 1 second), SVC (slow vital capacity), MVV (maximum voluntary ventilation), MIP (maximum inspiratory pressure), and MEP (maximum expiratory pressure). For FVC and FEV1, at least three acceptable attempts were made, and two of them were reproducible. SVC measurements were considered acceptable if the subject breathed into TLC then breathed out completely until flow had ceased for at least 1 s, and the two highest attempts varied by less than 200 ml. MVV was calculated by having the subject breathe in and out as rapidly and deeply as possible for 10 seconds. MIP and MEP were used as indices of respiratory muscle strength and measured with the subject in the seated position. Other parameters such as VC (vital capacity), ERV (expiratory reserve volume), and Vt (tidal volume) were also computed by the Cosmed spirometry.

A. *Statistical Analysis*

The statistical analysis was conducted using the SPSS software version 21. The data are presented as mean ± standard deviation. The relationship between BMI and spirometric parameters was analyzed using ANOVA test. The correlation between BMI and pulmonary function tests was determined using Pearson's Correlation test. A p-value of less than 0.05 was considered statistically significant

B. Descriptive Statistics

Table 1

S.No	PARAMETERS	N	Min	Max.	Mean	S.D
1	HEIGHT (cm)	111	115.00	185.00	173.40	9.98
2	WEIGHT (kg)	111	48.00	120.00	68.74	16.21
3	BMI	111	14.63	39.54	22.70	5.27
7	FEV1	111	1.91	6.05	3.70	0.77
8	FVC	111	1.84	8.57	3.31	0.92
9	FEV1/FVC	111	38.00	112.00	87.58	13.13
10	PEF	111	3.02	10.90	7.56	2.00
11	ERV	111	0.05	7.84	1.40	0.90
12	MVV	111	18.00	177.00	117.29	27.34
13	MIP	111	9.00	96.00	36.98	19.719
14	MEP	111	11.00	66.00	33.78	15.29

Table1 shows descriptive statistics of all parameters that had been analyzed in the different categories of BMI.

The study participants had a mean height of 173.41 ± 9.98 cm and a mean weight of 68.74 ± 16.21 kg, resulting in an average BMI of 22.70 ± 5.27. The pulmonary function parameters analysed in the study included Forced Expiratory Volume at 1 second (FEV1) with a mean value of 3.69 ± 0.78 litre/second, Forced Vital Capacity (FVC) with a mean of 3.31 ± 0.92 litre, and FEV1/FVC ratio with a mean value of 87.58 ± 13.13. The mean Peak Expiratory Flow (PEF) was 7.55 ± 2.00 litre/second, Expiratory reserve volume (ERV) was 3.01 ± 11.36 litre, and Maximum Voluntary Ventilation (MVV) was 117.28 ± 27.34 litre per minute. The mean maximum inspiratory pressure (MIP) was 36.98 ± 19.719 cm H_2O and the mean maximum expiratory pressure (MEP) was 33.78 ± 15.28 cm H_2O.

There was a mild positive correlation between normal weight and the spirometric parameters of FEV1 ($r = 0.060$) and PEF ($r=0.189$), although these correlations were not significant. On the other hand, there was a mild negative correlation between normal weight and FVC ($r = -0.130$), FEV1/FVC ($r = -0.075$), MVV ($r=-0.272$), MIF ($r=-0.212$), and MEF ($r=-0.113$).

The correlation between underweight and spirometric parameters was analyzed, and the results showed a mild positive correlation between underweight and FEV1/FVC ($r=0.162$), PEF ($r=0.249$), MVV ($r=0.11$), MIF ($r=0.276$), and MEF ($r=0.298$). However, these correlations were not significant. Additionally, a mild negative correlation was observed between underweight and FEV1 ($r=-0.107$), but this correlation was not significant. There may have been an error in recording the correlation for FVC, as a positive correlation between underweight and FVC does not make sense.

Based on the correlations, it seems that being overweight may have a mild positive effect on some spirometric parameters, such as FVC, FEV1/FVC, PEF, MVV, and MIF. However, these correlations were not significant, meaning that they could have occurred by chance and do not provide strong evidence of a relationship between being overweight and better lung function.

On the other hand, there was a mild negative correlation between being overweight and FEV1 and MEF, which were also not significant. This suggests that being overweight may have a slight negative effect on some spirometric parameters, such as FEV1 and MEF, but again, the lack of significance means that these findings could have occurred by chance.

Overall, it is important to note that correlation does not necessarily imply causation, and more research would be needed to determine whether there is a causal relationship between being overweight and spirometric parameters.

The study conducted a one-way ANOVA to compare the spirometric parameters (FEV1, FVC, FEV1/FVC, PEF, ERV, MVV, MIP, MEP) between the underweight, normal weight, and overweight groups. The results show that there was a statistically significant difference in FEV1 and ERV between the three BMI categories, with p-values of 0.003 and 0.005, respectively. However, there was no significant difference observed in FVC, FEV1/FVC, PEF, MVV, MIP, and MEP among the different BMI categories, with p-values of 0.15, 0.12, 0.73, 0.90, 0.49, and 0.722, respectively.

4. Discussion

The present study did not find a significant difference in forced vital capacity across all three BMI groups, which contradicts the findings of a study by Sudhir et al. in south Indian males aged 30 years and above, which showed a significant increase in FVC with increasing BMI, suggesting emphysematous changes in overweight individuals. However, our study was conducted in young adult males aged 18-19 years, which may explain the difference in results. Another cross-sectional study by Ahamed Azad et al. in sedentary young female adults found a significant reduction in FVC and a positive correlation with the underweight group compared to the normal weight group. Our study, on the other hand, did not find a significant correlation between FVC and underweight group in young adult males, which contradicts the previous study. It is important to note that the female lung volume is typically 10-12% smaller than that of males of the same age and height range, which may contribute to lower pulmonary function test values in females due to decreased respiratory muscle endurance and chest wall compliance. This could potentially explain the differing results in our study.

In our study, we investigated the relationship between BMI and FEV1, which is an important parameter for detecting airway obstruction. We found a significant reduction in FEV1 in underweight individuals compared to overweight and normal weight individuals. This result is consistent with previous studies conducted by K Soundarya et al and Vijetha et al. K Soundarya et al found that lung volumes were reduced in underweight individuals due to poor sources of body protein causing wasting of skeletal muscle, including respiratory muscles. In contrast, Vijetha et al observed that all pulmonary parameters, including FEV1, were reduced in overweight individuals due to increased fat mass in the chest and abdomen, leading to alterations in respiratory movements.

Our study results are further supported by other studies, such as Anugya Aparajitha et al, who found that increased BMI independently affects pulmonary function and the correlation pattern differs between males and females. A study conducted by Hasmuk Shah et al on adolescent boys also showed that underweight individuals had reduced dynamic lung parameters, including FEV1. Similarly, Kalpojith Saikia et al found a reduction in FEV1 in overweight individuals, which is consistent with our study.

However, some studies have reported different results. For example, Saikia et al found a significant negative correlation between BMI and FVC and FEV1, which contradicts our findings. Umesh Pralhadrao et al also reported a reduction in FEV1 in underweight and overweight groups, as well as FVC and FEF25-75%, which is not consistent with our results. Additionally, Mohamed Ai Ghlobain et al found that obesity did not have an effect on spirometry tests, except for PEF, in a Saudi Arabian population.

Age and ethnic differences could be a possible reason for the discrepancies in the results of different studies. Our study was conducted on South Indian adult males aged 18-19 years, which could influence the pulmonary function test results.

Based on the information provided, it appears that there is no significant relationship between BMI and FEV1/FVC ratio in the study being referred to. However, other studies have found significant correlations between BMI and FEV1/FVC ratio, suggesting that the relationship may be complex and dependent on a variety of factors such as gender, age, and underlying lung conditions. It is important to note that the interpretation of lung function tests, including FEV1/FVC ratio, should be done in the context of a comprehensive clinical evaluation and not solely based on BMI.

Based on the studies mentioned, it seems that the relationship between BMI and PEF is complex and influenced by multiple factors such as gender, muscle strength, and fat distribution. Some studies have found a significant decrease in PEF in overweight individuals compared to normal or underweight individuals, while others have found no significant difference. Similarly, some studies have found a significant decrease in PEF in females compared to males in both underweight and overweight groups, while others have not found such a gender difference. The ethnicity and age group of the study subjects may also play a role in the results. Overall, it appears that further research is needed to fully understand the relationship between BMI and PEF.

5. Conclusion

Based on the findings of the various studies reviewed, it can be concluded that there is a relationship between BMI and pulmonary function. Obesity and underweight are associated with reduced lung volumes and compliance, which affects the static lung function. Overweight and obese individuals are also more likely to have a reduced expiratory reserve volume due to the deposition of adipose tissue in the chest wall and abdominal areas. Underweight individuals, on the other hand, have poor respiratory muscle strength due to poor respiratory and diaphragmatic muscle mass, which impairs their ability to generate inspiratory force and reduces their lung volume.

The dynamic lung function is also affected by underweight, which results in obstructive-type dysfunction. However, the findings regarding the effect of overweight on dynamic lung function are contradictory. Some studies found a significant decrease in FEV1, while others did not find any significant difference between normal weight and overweight groups.

In conclusion, maintaining a normal BMI is essential for optimal respiratory function. Further research is needed to understand the underlying mechanisms that contribute to the relationship between BMI and pulmonary function, particularly in different populations and ethnicities.

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