Section: Physiology

Original Research Article

# THE WEIGHT OF BREATHING: ASSESSING FVC, $FEV_1$, MVV, PEF, AND ERV ACROSS BMI CATEGORIES

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**ABSTRACT**

**Background:** Obesity alters respiratory mechanics, while undernutrition reduces respiratory muscle mass and diaphragmatic strength, leading to decreased pulmonary function. Limited studies have compared pulmonary function across different BMI categories. **Aim:** To categorize subjects according to Body Mass Index (BMI), and to assess pulmonary function parameters (FVC, $FEV_1$, MVV, PEF, and ERV), and determine their association with BMI.

**Materials and Methods:** This prospective cross-sectional study included 111 male medical students from Trichy SRM Medical College Hospital and Research Centre, Tiruchirappalli. Participants were categorized as underweight, normal weight, or overweight based on BMI. Anthropometric measurements, including height, weight, waist circumference, hip circumference, waist-to-hip ratio, and BMI, were recorded. Pulmonary function tests (FVC, $FEV_1$, MVV, PEF, and ERV) were performed using a computerized COSMED spirometer. Statistical analysis was conducted using SPSS version 21. One-way ANOVA was used to compare pulmonary function among BMI groups, and Pearson's correlation test assessed the relationship between BMI and pulmonary function. A p-value <0.05 was considered statistically significant.

**Results:** Significant differences were observed in $FEV_1$ ($p = 0.003$) and ERV ($p = 0.005$) among the BMI groups. No significant differences were found in FVC ($p = 0.15$), $FEV_1$/FVC ratio ($p = 0.12$), PEF ($p = 0.73$), or MVV ($p = 0.90$).

**Conclusion:** ERV was significantly altered in both underweight and overweight participants, while $FEV_1$ was reduced in the underweight group. Maintaining a normal BMI may help preserve optimal pulmonary function.

**Keywords:** obesity, underweight, FVC, FEV1, MVV, PEF and ERV.

## INTRODUCTION

Respiratory diseases are a major cause of morbidity and premature mortality worldwide, and pulmonary function tests (PFTs) are essential tools for diagnosing respiratory disorders, assessing disease severity, monitoring disease progression, and evaluating treatment outcomes.[1] Pulmonary function is influenced by several factors, including age, sex, height, ethnicity, physical activity, environmental conditions, smoking, and nutritional status[1]. Among these, nutritional status, commonly assessed using Body Mass Index (BMI), has emerged as an important determinant of respiratory health.[2]

India is currently undergoing a nutritional transition characterized by the coexistence of undernutrition and overweight/obesity, resulting in a "double burden of malnutrition".[3] Rapid urbanization, lifestyle changes, and altered dietary patterns have contributed to an increasing prevalence of overweight and obesity, while under nutrition continues to remain a significant public health problem.[2] Both extremes of BMI are associated with adverse health outcomes and contribute to the growing burden of non-communicable diseases.[4]

Abnormal BMI has a significant impact on pulmonary function.[4] Obesity impairs respiratory mechanics by reducing chest wall compliance, decreasing respiratory muscle efficiency, and lowering lung volumes such as functional residual capacity and expiratory reserve volume.[2,5] Conversely, underweight individuals often have reduced respiratory muscle mass and strength due to undernutrition, resulting in decreased pulmonary function parameters such as forced vital capacity (FVC) and forced expiratory volume in one second ($FEV_1$).[2,5] Thus, both underweight and overweight states may adversely affect respiratory function through different physiological mechanisms.

Although several studies have investigated the effect of obesity on pulmonary function, comparatively fewer studies have evaluated pulmonary function in underweight individuals or compared respiratory function across underweight, normal-weight, and overweight groups. Therefore, there is a need to comprehensively assess pulmonary function across different BMI categories. The present study was undertaken to compare pulmonary function among underweight, normal-weight, and overweight individuals, thereby improving the understanding of the relationship between BMI and respiratory function and providing evidence for early identification and preventive interventions in individuals at risk.

## MATERIALS AND METHODS

**Study Design:** Prospective Cross Sectional Study

**Study Setting:**

This study was conducted at Trichy SRM Medical Hospital & Research center, Irungalur, Trichy. Anthropometric measurements & Spirometry recording were performed at the Research lab of Department of Physiology.

**Study Duration:** one & half years

**Selection of Subjects:**

The healthy volunteers were selected for this study using simple randomization technique.

**Sample Size:**

The calculated sample size was 111 with 90% power and 95% confidence interval.[6]

Study Population: Male medical Students studying in TSRMMCH& RC, Irungalur, Trichy.

**Inclusion Criteria**

- Healthy male students,
- 3 categories of BMI {normal, underweight, overweight} were included in the study.

**Exclusion Criteria**

- Obese males,
- Students who are smokers & drug abusers, with musculoskeletal chest deformity,
- With respiratory & cardiovascular illness were excluded from the study.[7]

Participants were classified into three BMI categories: According to WHO criteria.

- Underweight (BMI <18.5 $Kg/M^2$),
- Normal Weight (18.5–24.9 $Kg/M^2$), And
- Overweight (25.0–29.9 $kg/m^2$)

Institutional Ethics Committee approval was obtained, and written informed consent was taken from all participants before enrolment.

Anthropometric measurements were recorded with participants wearing light clothing. Height was measured using a stadiometer, and weight was measured using a calibrated weighing scale. Body Mass Index (BMI) was calculated using Quetelet's formula: BMI = Weight (kg)/Height ($m^2$). Waist circumference was measured midway between the lower costal margin and the iliac crest, while hip circumference was measured at the maximum circumference over the buttocks. Waist-to-hip ratio (WHR) was subsequently calculated.

Pulmonary function tests were performed using a computerized COSMED spirometer following American Thoracic Society (ATS) guidelines. The spirometer was calibrated before each testing session. All tests were conducted in the sitting position between 4:00 PM and 6:00 PM. Participants were instructed regarding the procedure and performed the manoeuvres while wearing a nose clip, following maximal inspiration and forceful expiration. A minimum of three acceptable manoeuvres (maximum of eight attempts) were recorded, and the highest acceptable value was used for analysis.

The pulmonary function parameters assessed included Forced Vital Capacity (FVC), Forced Expiratory Volume in one second ($FEV_1$), Slow Vital Capacity (SVC), and Maximum Voluntary Ventilation (MVV). FVC and $FEV_1$ measurements were accepted when they met ATS criteria for acceptability and reproducibility. SVC was considered acceptable when expiration continued until airflow ceased, while MVV was measured during rapid and deep breathing over 10 seconds and expressed as litres per minute.

The collected data were expressed as mean ± standard deviation (SD) and analysed using Statistical Package for Social Sciences (SPSS) version 21. Differences in pulmonary function parameters among BMI groups were analysed using one-way Analysis of Variance (ANOVA), while the relationship between BMI and pulmonary function parameters was assessed using Pearson's correlation coefficient. A p-value <0.05 was considered statistically significant.

## RESULTS

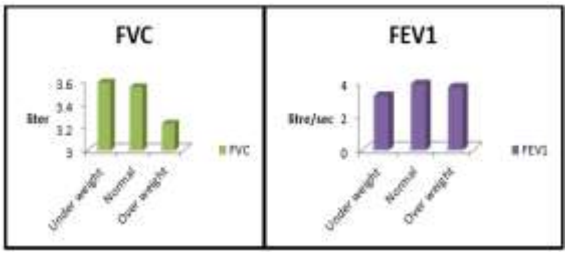


**Figure 1: Comparison of Forced Expiratory Volume at first second, Forced Vital Capacity among 3 groups of BMI**

This test result shows that there is a significant variation in FEV1 among 3 groups ($p < 0.01$).
FVC was not statistically significant.

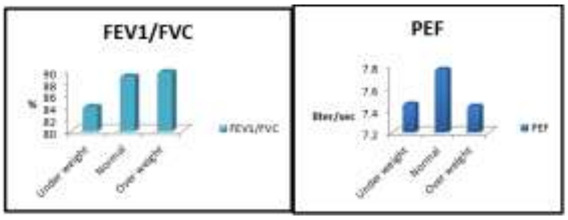


**Figure 2: Comparison of FEV1/FVC & Peak Expiratory Flow among 3 groups of BMI**

FEV1/FVC was not statistically significant. PEF did not show any significance ($p = 0.734$).

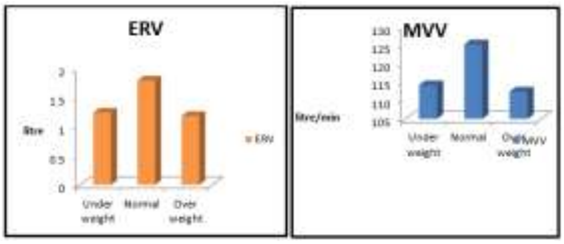


**Figure 3: Comparison of Expiratory Reserve Volume & Maximum Voluntary Ventilation among 3 groups of BMI**

ERV shows a highly significance ($p = 0.005$). MVV did not show any statistically significance ($p = 0.09$).

**Table 1: Comparison of Forced Expiratory Volume at first second, Forced Vital Capacity among underweight, normal & overweight**

| | Forced Expiratory Volume at first second | | | Forced Vital Capacity | | |
|---|---|---|---|---|---|---|
| **Group** | **Mean ± SD** | **95% CI** | **P-Value** | **Mean ± SD** | **95% CI** | **P-Value** |
| Underweight | 3.16 ± 1.07 | | | 3.58 ± 0.89 | | |
| Normal | 3.84 ± 0.71 | 3.381 to 3.72 | 0.003** | 3.54 ± 1.01 | 3.290 to 3.612 | 0.15 |
| Overweight | 3.66 ± 0.73 | | | 3.23 ± 0.60 | | |

***p value<0.05, ** p value <0.01, *** p value <0.001**

**Table 2: Comparison of FEV1/FVC & Peak Expiratory Flow among Underweight, Normal & Overweight**

| | FEV1/FVC | | | Peak Expiratory Flow | | |
|---|---|---|---|---|---|---|
| **Group** | **Mean ± SD** | **95% CI** | **P-Value** | **Mean ± SD** | **95% CI** | **P-Value** |
| Underweight | 84±15.67 | | | 7.46 ± 2.25 | | |
| Normal | 89.03 ± 12.03 | 85.12 to 90.06 | 0.123 | 7.77 ± 1.95 | 7.178 to 7.934 | 0.734 |
| Overweight | 89.73± 10.49 | | | 7.44 ± 1.85 | | |

***p value<0.05, ** p value <0.01, *** p value <0.001**

**Table 3: Comparison of Expiratory Reserve Volume & Maximum Voluntary Ventilation among Underweight, Normal & Overweight**

| | Expiratory Reserve Volume | | | Maximum Voluntary Ventilation | | |
|---|---|---|---|---|---|---|
| **Group** | **Mean ± SD** | **95% CI** | **P-Value** | **Mean ± SD** | **95% CI** | **P-Value** |
| Underweight | 1.24 ± 0.50 | | | 114.16 ± 17.09 | | |
| Normal | 1.79 ± 1.26 | 1.234 to 1.574 | 0.005* | 125.26 ± 23.20 | 112.144 to 122.432 | 0.09 |
| Overweight | 1.18 ± 0.65 | | | 112.44± 36.81 | | |

***p value<0.05, ** p value <0.01, *** p value <0.001**

**Table 4: Correlation between BMI categories & pulmonary function test**

| BMI | Pulmonary Parameters | Correlation Coefficient ('r' Value) | P value | Interpretation |
|---|---|---|---|---|
| Normal weight | **FEV1** | 0.06 | 0.724 (NS) | Positive correlation |
| | **FVC** | - 0.13 | 0.443 (NS) | Negative Correlation |
| | **FEV1/FVC** | - 0.07 | 0.659 (NS) | Negative Correlation |
| | **PEF** | 0.19 | 0.262 (NS) | Positive Correlation |
| | **MVV** | - 0.27 | 0.103 (NS) | Negative Correlation |
| Under weight | **FEV1** | - 0.10 | 0.528 (NS) | Negative correlation |
| | **FVC** | - 0.14 | 0.408 (NS) | Negative Correlation |

| | | | | |
|---|---|---|---|---|
| | FEV1/FVC | 0.162 | 0.339 (NS) | Positive Correlation |
| | PEF | 0.249 | 0.137 (NS) | Positive Correlation |
| | MVV | 0.11 | 0.518 (NS) | Positive Correlation |
| Over weight | FEV1 | - 0.05 | 0.782 (NS) | Negative correlation |
| | FVC | 0.02 | 0.887 (NS) | Positive Correlation |
| | FEV1/FVC | 0.16 | 0.407 (NS) | Positive Correlation |
| | PEF | 0.06 | 0.71 (NS) | Positive Correlation |
| | MVV | 0.13 | 0.452 (NS) | Positive Correlation |

**NS- non significant**

Correlation analysis showed no statistically significant association between BMI and the spirometric parameters in any group. In the normal-weight group, FEV1 and PEF showed mild positive correlations, while FVC, FEV1/FVC, and MVV showed mild negative correlations. In the underweight group, FEV1/FVC, PEF, and MVV demonstrated mild positive correlations, whereas FVC and FEV1 showed mild negative correlations, indicating reduced lung compliance. In the overweight group, FVC, FEV1/FVC, PEF, and MVV showed mild positive correlations, while FEV1 demonstrated a mild negative correlation. Overall, the observed correlations were weak and statistically non-significant, suggesting that BMI had only a limited influence on spirometric parameters in the study population.

**Table 5: One Way ANOVA -Between BMI & Spirometric Parameters**

| Parameters | Groups | Mean | S.D | F Value | P value |
|---|---|---|---|---|---|
| FEV1 | Under weight (N = 37) | 3.1551 | 1.07273 | 6.309 | 0.003** |
| | Normal weight (N = 37) | 3.8376 | 0.71331 | | |
| | Over weight (N=37) | 3.6562 | 0.7339 | | |
| FVC | Under weight (N = 37) | 3.5822 | 0.88791 | 1.932 | 0.15 |
| | Normal weight (N = 37) | 3.543 | 1.00952 | | |
| | Over weight (N=37) | 3.2281 | 0.59756 | | |
| FEV1/FVC | Under weight (N = 37) | 84 | 15.668 | 2.139 | 0.123 |
| | Normal weight (N = 37) | 89.03 | 12.296 | | |
| | Over weight (N=37) | 89.73 | 10.492 | | |
| PEF | Under weight (N = 37) | 7.4592 | 2.24711 | 0.31 | 0.734 |
| | Normal weight (N = 37) | 7.77 | 1.94562 | | |
| | Over weight (N=37) | 7.4405 | 1.85065 | | |
| ERV | Under weight (N = 37) | 1.2414 | 0.49627 | 5.486 | 0.005** |
| | Normal weight (N = 37) | 1.7895 | 1.26435 | | |
| | Over weight (N=37) | 1.1835 | 0.64641 | | |
| MVV | Under weight (N = 37) | 114.16 | 17.0882 | 2.46 | 0.09 |
| | Normal weight (N = 37) | 125.26 | 23.198 | | |
| | Over weight (N=37) | 112.44 | 36.8121 | | |
| | Normal weight (N = 37) | 33.32 | 16.846 | | |
| | Over weight (N=37) | 31.92 | 15.054 | | |

***p value<0.05, ** p value <0.01, *** p value <0.001**

Table-19 shows the relationship between BMI and spirometric parameters. As per the one way ANOVA table , a statistically significant difference was observed with Forced expiratory volume at first second (p = 0.003) and Expiratory Reserve Volume (p =0.005 ) between underweight, normal and overweight groups. There was no difference observed with FVC (p = 0.15), FEV1/FVC (p=0.12), PEF (p=0.73), MVV(p=0.90), among different categories of BMI.

## DISCUSSION

Overweight male medical students and found a U-shaped relationship between BMI and lung function, with reduced pulmonary performance observed in both underweight and overweight groups compared to those with normal BMI. Forced Vital Capacity (FVC) showed no significant differences across BMI categories, unlike several previous studies that reported reduced FVC in underweight or overweight individuals.[8] These differences may be attributed to variations in age, sex, and study populations. In contrast, Forced Expiratory Volume in one second (FEV1) was significantly reduced in both underweight and overweight participants, supporting earlier findings that under nutrition weakens respiratory muscles, while excess body fat restricts chest wall and diaphragmatic movement, leading to impaired lung function.[7]

The FEV1/FVC ratio and Peak Expiratory Flow (PEF) did not differ significantly among the BMI groups in the present study, although PEF showed a declining trend in both underweight and overweight participants. These findings differ from some previous studies that reported significant reductions in these parameters, possibly due to differences in ethnicity, gender, age, and body composition.[9] The absence of significant changes in the FEV1/FVC ratio suggests that BMI-related alterations in pulmonary function may be more closely associated with restrictive rather than obstructive changes in lung mechanics.

Similarly, Expiratory Reserve Volume (ERV) and Maximum Voluntary Ventilation (MVV) showed no significant association with BMI, which contrasts with studies reporting decreased values in overweight individuals. Overall, the present findings indicate that both low and high BMI adversely affect pulmonary function, particularly FEV1, while other spirometric parameters remain relatively unaffected in young adult males. Variations between the present study and previous research are likely due to differences in demographic characteristics, study design, and physiological factors, emphasizing the need to consider BMI as an important determinant of respiratory health.

## CONCLUSION

Obesity is a major global health problem that adversely affects respiratory function through excessive adipose tissue deposition, leading to reduced lung volumes and chest wall compliance6. This study evaluated pulmonary function across underweight, normal-weight, and overweight individuals and found that Expiratory Reserve Volume (ERV), a static lung function parameter, was significantly reduced in the overweight group due to mechanical restriction of the chest wall and diaphragm10. In the underweight group, Forced Expiratory Volume in one second (FEV1), a dynamic lung function parameter, was significantly reduced, likely because of poor respiratory muscle strength and decreased diaphragmatic muscle mass, indicating impaired ventilatory mechanics. Overall, the findings demonstrate that both underweight and overweight individuals exhibit compromised pulmonary function, emphasizing that maintaining a normal Body Mass Index (BMI) is essential for optimal respiratory health.

**Limitations of the Study**

This study was limited by its small sample size, cross-sectional design, and single-institution setting, which may affect the generalizability of the findings. Only young male participants were included, excluding females and other age groups. Comparisons between measured and predicted pulmonary function values were not performed, and grading of FVC, FEV1, and FEV1/FVC ratio was not carried out. Additionally, Diffusing Capacity of the Lungs for Carbon Monoxide (DLCO), an important pulmonary parameter evaluated in previous studies, was not included.

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