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Original Research Article

Comparative Study of Pulmonary Function Tests Using Spirometry in Obese Versus Sedentary Individuals

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Abstract

Background: Obesity is a burgeoning global epidemic associated with multi-system dysfunction. Its impact on respiratory mechanics and pulmonary function — though clinically significant — remains underexplored in Indian settings. Spirometry offers a non-invasive, reproducible means of assessing respiratory capacity, and this study exploits that to compare pulmonary function between obese and sedentary individuals. Objective of this study is to compare spirometric indices — Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), FEV1/FVC ratio, Peak Expiratory Flow Rate (PEFR), Forced Expiratory Flow 25–75% (FEF25–75%), and accessory lung volumes — between obese and sedentary non-obese individuals; and to assess the correlation of Body Mass Index (BMI) with these spirometric parameters.

Methods: A cross-sectional comparative study was conducted at Department of Physioliogy, Government Medical College Krishnagiri for a period of six months in individuals (BMI ≥ 30 kg/m²) and 60 sedentary non-obese controls (BMI 18.5–24.9 kg/m²). Spirometry was performed using a calibrated computerised spirometer following American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines. Statistical analysis was done using SPSS version 26.0.

Results: Obese individuals demonstrated significantly lower FVC (3.12 ± 0.61 L vs 3.74 ± 0.58 L; $p < 0.001$), FEV1 (2.48 ± 0.52 L vs 3.02 ± 0.49 L; $p < 0.001$), PEFR (6.21 ± 1.18 L/sec vs 7.54 ± 1.22 L/sec; $p < 0.001$), and FEF25–75% (2.89 ± 0.74 vs 3.47 ± 0.68 L/sec; $p < 0.001$) compared to sedentary controls. The FEV1/FVC ratio was preserved in both groups (79.6% vs 80.8%; $p = 0.194$), indicating a predominantly restrictive pattern. Expiratory Reserve Volume (ERV) was markedly reduced in obese participants (0.68 ± 0.21 L vs 1.14 ± 0.28 L; $p < 0.001$). Restrictive spirometric pattern was observed in 53.3% of obese individuals compared to 16.7% in sedentary controls ($p < 0.001$). BMI showed a significant negative correlation with FVC ($r = -0.61$), FEV1 ($r = -0.58$), ERV ($r = -0.67$), and PEFR ($r = -0.54$).

Conclusion: Obesity exerts a profound adverse effect on pulmonary function, primarily producing a restrictive ventilatory defect. Early spirometric screening in obese individuals is warranted for timely respiratory intervention and comprehensive metabolic management.

Keywords: Spirometry; Pulmonary Function Tests; Obesity; Body Mass Index; Restrictive Lung Disease; Forced Vital Capacity; Sedentary Lifestyle; Respiratory Mechanics.

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Introduction

Over 650 million adults worldwide suffer from obesity, which has become one of the most important public health issues of the twenty-first century. This burden is increasing in low- and middle-income nations like India. [1] The World Health Organization (WHO) defines obesity as a Body Mass Index (BMI) of 30 kg/m² or more. Obesity is a complex multifactorial condition caused by a combination of environmental factors, sedentary lifestyle, excess calories, hormonal dysregulation, and genetic susceptibility. [2] Cardiovascular illness, type 2 diabetes mellitus, musculoskeletal conditions, obstructive sleep apnea, and increasingly acknowledged respiratory function deficits are among its systemic effects. The respiratory system is particularly susceptible to the inflammatory and mechanical effects of obesity. Particularly in the supine or semi-

recumbent positions, abdominal and thoracic adipose accumulation lowers chest wall compliance, raises the diaphragm, and prevents full lung expansion. [3] Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Expiratory Reserve Volume (ERV), and Peak Expiratory Flow Rate (PEFR) are among the measurable spirometric deficits that result from these anatomical abnormalities, which together produce a primarily restrictive ventilatory pattern. [4] Additionally, obesity-induced low-grade systemic inflammation, which is mediated by adipokines including leptin and tumor necrosis factor-alpha, may further impair small airway function and airway responsiveness, which would lower FEF25–75%. [5]

The gold-standard pulmonary function test (PFT) is spirometry, which offers consistent, repeatable, and comprehensible ventilatory capacity measures. The European Respiratory Society (ERS) and the American Thoracic Society (ATS) have developed technical standards and normative criteria that allow comparisons between populations and clinical settings. [6] Spirometry is underutilized in the routine assessment of obese patients, who are instead predominantly followed for metabolic and cardiovascular endpoints, despite its clinical usefulness.

Reduced cardiorespiratory reserve, decreased thoracic excursion, and deconditioning of the respiratory muscles are all separate respiratory risks associated with a sedentary lifestyle, which is defined by low levels of physical activity even in the absence of obesity. [7] However, it is still unclear how much obesity and sedentary behavior contribute to spirometric anomalies, particularly in Indian communities who exhibit unique anthropometric and ethnic traits.

The link between obesity and poor pulmonary function has been shown in a number of international studies, but there is still a dearth of data in India, especially when it comes to studies that thoroughly compare obese and sedentary non-obese people using standardized spirometric protocols and population-appropriate reference values. Given the high frequency of metabolic syndrome and abdominal obesity in South Asian populations, even at lower BMI thresholds, this disparity is clinically relevant. [8]

The present study was therefore designed to conduct a detailed comparative analysis of spirometric indices between obese and sedentary non-obese participants, and to quantify the relationship between anthropometric measures — particularly BMI and waist circumference — and pulmonary function test parameters. The findings are intended to inform early respiratory screening protocols in the context of obesity management.

The primary objective of this study was to compare spirometric parameters — including FVC, FEV1, FEV1/FVC ratio, PEFR, FEF25–75%, ERV, IRV, and Inspiratory Capacity (IC) — between obese and sedentary non-obese individuals. The secondary objectives were to assess the correlation of BMI and waist circumference with each spirometric index in both groups, and to determine the prevalence and severity of spirometric pattern abnormalities (restrictive, obstructive, and mixed) in the obese cohort compared to sedentary controls.

Materials and Methods

This cross-sectional comparative observational study was conducted over 6 months in the Department of Physiology at Government Medical College, Krishnagiri, after Institutional Ethics Committee approval and informed consent, in accordance with the Declaration of Helsinki. A total of 120 adults were recruited using purposive sampling and divided into two groups: obese (BMI $\geq$ 30 kg/m², n = 60) and sedentary non-obese controls (BMI 18.5–24.9 kg/m², n = 60) with <150 minutes/week physical activity as per WHO guidelines. Participants aged 18–60 years of either sex were included.

Individuals with respiratory diseases, cardiovascular conditions, neuromuscular disorders, pregnancy, recent surgeries, recent respiratory infections, significant smoking history (>10 pack-years), or inability to perform spirometry were excluded.

Anthropometric measurements (height, weight, BMI, waist circumference) were recorded using standardised methods, with averages of three readings taken. Spirometry was performed using a calibrated Schiller SP-1 spirometer following ATS/ERS 2019 guidelines, with daily calibration using a 3-L syringe. Testing was conducted between 8:00–11:00 AM under standardised conditions.

Participants performed at least three acceptable FVC manoeuvres (maximum eight attempts). Acceptability and repeatability criteria were maintained as per ATS/ERS standards, and the best values were recorded. Predicted values were based on ICMR reference equations. [9,10]

Measured parameters included FVC, FEV1, FEV1/FVC ratio, PEFR, FEF25–75%, ERV, IRV, TV, IC, and VC. Spirometric patterns were classified as restrictive (FVC < 80% predicted with normal/high FEV1/FVC), obstructive (FEV1/FVC < 70%), or mixed. Restriction severity was graded as mild (70–79%), moderate (50–69%), and severe (<50%).

All data were entered into Microsoft Excel and subsequently analysed using IBM SPSS Statistics,

Version 26.0. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequency and percentage. Group comparisons for continuous variables were performed using the independent samples two-tailed Student's t-test for normally distributed data. Categorical variables were compared using Pearson's chi-square test.

Pearson's correlation coefficient was computed to assess the strength and direction of the linear relationship between anthropometric variables (BMI, waist circumference) and spirometric parameters within each group.

A p-value < 0.05 was considered statistically significant at a 95% confidence interval.

Results

Baseline Demographic and Anthropometric Characteristics: Table 1 presents the demographic and anthropometric characteristics of both study groups. The two groups were well-matched with respect to age (38.4 ± 7.2 years vs 37.9 ± 6.8 years; p = 0.721), gender distribution (Male/Female: 34/26 vs 32/28; p = 0.689), height (168.3 ± 8.4 cm vs 169.1 ± 7.9 cm; p = 0.608), and smoking status (p = 0.793), ensuring that observed differences in spirometric parameters were attributable to BMI rather than confounding demographic variables. As expected, the obese group demonstrated significantly higher body weight (95.6 ± 12.3 kg vs 71.2 ± 9.6 kg; p < 0.001), BMI (33.8 ± 3.1 vs 24.9 ± 2.4 kg/m²; p < 0.001), and waist circumference (104.2 ± 10.1 cm vs 84.5 ± 8.2 cm; p < 0.001) compared to sedentary controls.

Table 1: Baseline demographic and anthropometric characteristics of obese and sedentary groups

Variable	Obese Group (n = 60)	Sedentary Group (n = 60)	p-value
Age (years)	38.4 ± 7.2	37.9 ± 6.8	0.721
Gender (Male/Female)	34/26	32/28	0.689
Height (cm)	168.3 ± 8.4	169.1 ± 7.9	0.608
Weight (kg)	95.6 ± 12.3	71.2 ± 9.6	< 0.001*
BMI (kg/m²)	33.8 ± 3.1	24.9 ± 2.4	< 0.001*
Waist Circumference (cm)	104.2 ± 10.1	84.5 ± 8.2	< 0.001*
Smoker (Yes/No)	8/52	7/53	0.793

*** Statistically significant (p < 0.05). Values are expressed as Mean ± SD unless otherwise specified.**

Comparison of Primary Spirometric Parameters: Table 2 summarises the primary spirometric parameters for both groups. Obese individuals exhibited statistically significant reductions across all major flow-volume and volume-time parameters compared to sedentary non-obese controls. FVC was markedly reduced in the obese group (3.12 ± 0.61 L vs 3.74 ± 0.58 L; p < 0.001), with corresponding decrements in percent predicted values (76.4 ± 9.2% vs 89.8 ± 7.6%). FEV1 was similarly reduced (2.48 ± 0.52 L vs 3.02 ± 0.49 L; p < 0.001). Crucially, the FEV1/FVC ratio was preserved in both groups (79.6 ± 5.1% vs 80.8 ± 4.7%; p = 0.194), confirming that the predominant ventilatory defect in the obese group was restrictive rather than obstructive.

PEFR (6.21 ± 1.18 L/sec vs 7.54 ± 1.22 L/sec; p < 0.001) and FEF25–75% (2.89 ± 0.74 vs 3.47 ± 0.68 L/sec; p < 0.001) were also significantly impaired in obese individuals.

Table 2: Comparison of primary spirometric parameters between obese and sedentary groups

Parameter	Obese Group (Mean ± SD)	Sedentary Group (Mean ± SD)	p-value
FVC (L)	3.12 ± 0.61	3.74 ± 0.58	< 0.001*
FVC % Predicted	76.4 ± 9.2	89.8 ± 7.6	< 0.001*
FEV1 (L)	2.48 ± 0.52	3.02 ± 0.49	< 0.001*
FEV1 % Predicted	74.1 ± 8.7	88.3 ± 7.1	< 0.001*
FEV1/FVC Ratio (%)	79.6 ± 5.1	80.8 ± 4.7	0.194
PEFR (L/sec)	6.21 ± 1.18	7.54 ± 1.22	< 0.001*
FEF25–75% (L/sec)	2.89 ± 0.74	3.47 ± 0.68	< 0.001*

*** Statistically significant (p < 0.05). FVC = Forced Vital Capacity; FEV1 = Forced Expiratory Volume in 1 second; PEFR = Peak Expiratory Flow Rate; FEF25–75% = Forced Expiratory Flow 25–75%; SD = Standard Deviation.**

Lung Volume Parameters: Accessory lung volume parameters are detailed in Table 3. Expiratory Reserve Volume (ERV), the most gravity-dependent lung volume, was profoundly reduced in the obese group compared to sedentary controls (0.68 ± 0.21 L vs 1.14 ± 0.28 L; p < 0.001). This reduction is mechanistically attributed to the cephalad displacement of the diaphragm by excessive intra-abdominal and thoracic fat, which curtails the capacity for additional exhalation below the functional residual capacity.

Inspiratory Reserve Volume (IRV) was likewise significantly lower in obese individuals (1.82 ± 0.44 L vs 2.36 ± 0.51 L; $p < 0.001$), as was Inspiratory Capacity (2.30 ± 0.48 L vs 2.87 ± 0.54 L; $p < 0.001$) and Vital Capacity (2.98 ± 0.56 L vs 3.72 ± 0.61 L; $p < 0.001$). Tidal Volume did not differ significantly between the groups (0.48 ± 0.09 L vs 0.51 ± 0.08 L; $p = 0.063$), suggesting that resting breathing efficiency was relatively maintained despite the reduced reserve volumes.

Table 3: Comparison of accessory lung volume parameters between obese and sedentary groups

Parameter	Obese Group (Mean ± SD)	Sedentary Group (Mean ± SD)	p-value
ERV (L)	0.68 ± 0.21	1.14 ± 0.28	< 0.001*
IRV (L)	1.82 ± 0.44	2.36 ± 0.51	< 0.001*
TV (L)	0.48 ± 0.09	0.51 ± 0.08	0.063
IC (L)	2.30 ± 0.48	2.87 ± 0.54	< 0.001*
VC (L)	2.98 ± 0.56	3.72 ± 0.61	< 0.001*

*** Statistically significant ($p < 0.05$). ERV = Expiratory Reserve Volume; IRV = Inspiratory Reserve Volume; TV = Tidal Volume; IC = Inspiratory Capacity; VC = Vital Capacity.**

Correlation between BMI and Spirometric Parameters: Table 4 presents the Pearson's correlation coefficients between BMI and waist circumference with spirometric parameters in both groups. In the obese group, BMI showed a strong negative correlation with ERV ($r = −0.67$; $p < 0.001$), FVC ($r = −0.61$; $p < 0.001$), waist circumference versus FVC ($r = −0.63$; $p < 0.001$), FEV1 ($r = −0.58$; $p < 0.001$), PEFR ($r = −0.54$; $p < 0.001$), and FEF25–75% ($r = −0.49$; $p < 0.001$). These correlations were substantially weaker and less clinically significant in the sedentary group, though statistically significant values were obtained for most parameters.

The strength of inverse correlation in the obese group underscores that increasing adiposity — as quantified by both BMI and waist circumference — exerts a progressively greater mechanical burden on respiratory function.

Table 4: Pearson's correlation between BMI / waist circumference and spirometric parameters

Spirometric Parameter	Pearson r (Obese)	Pearson r (Sedentary)	Significance
BMI vs FVC	−0.61	−0.22	< 0.001*
BMI vs FEV1	−0.58	−0.19	< 0.001*
BMI vs PEFR	−0.54	−0.17	< 0.001*
BMI vs ERV	−0.67	−0.25	< 0.001*
BMI vs FEF25–75%	−0.49	−0.16	< 0.001*
Waist Circ. vs FVC	−0.63	−0.21	< 0.001*

*** Statistically significant ($p < 0.05$). Negative r values indicate inverse correlation.**

Spirometric Pattern Classification: Table 5 displays the distribution of spirometric patterns across both groups. A normal spirometric pattern was found in only 36.7% of obese individuals compared to 80.0% of sedentary controls ($p < 0.001$). A restrictive ventilatory pattern was the predominant abnormality in the obese group, occurring in 53.3% compared to 16.7% in controls ($p < 0.001$). The severity of restriction was also significantly greater in the obese cohort: moderate restriction was present in 20.0% of obese participants versus 3.3% in sedentary controls ($p = 0.004$), while severe restriction was detected exclusively in the obese group (10.0% vs 0.0%; $p = 0.011$).

Obstructive and mixed patterns were infrequent in both groups, with no statistically significant between-group differences.

Table 5: Spirometric pattern classification in obese and sedentary groups

Classification	Obese Group n (%)	Sedentary Group n (%)	p-value
Normal Pattern	22 (36.7%)	48 (80.0%)	< 0.001*
Restrictive Pattern	32 (53.3%)	10 (16.7%)	< 0.001*
Obstructive Pattern	4 (6.7%)	2 (3.3%)	0.396
Mixed Pattern	2 (3.3%)	0 (0.0%)	0.154
Mild Restriction	14 (23.3%)	8 (13.3%)	0.164
Moderate Restriction	12 (20.0%)	2 (3.3%)	0.004*
Severe Restriction	6 (10.0%)	0 (0.0%)	0.011*

*** Statistically significant ($p < 0.05$). Restrictive pattern: FVC < 80% predicted with normal/raised FEV1/FVC; Obstructive: FEV1/FVC < 70%; Mixed: both criteria met.**

Discussion

The results of the current comparative cross-sectional survey indicate that obesity has a multifaceted and clinically significant adverse impact on pulmonary function, characterised by a predominantly restrictive ventilatory defect with significant reductions in FVC, FEV1, ERV, PEFR, and FEF25-75%, with a relatively preserved FEV1/FVC ratio. These findings support the pathophysiological model of obesity-induced respiratory impairment that was originally conceived by Salome et al. in terms of a mechanical effect of fat on thoracoabdominal excursion. [11,12]

The significant reduction in ERV observed in the obese group (0.68 L vs 1.14 L; $p < 0.001$) is discussed below. ERV is the lung volume that is most sensitive to the effects of obesity. ERV is the lung volume that reflects the ability to exhale below the normal resting expiratory position. The obese patient experiences an inward-compressive force on the chest wall due to the accumulation of visceral and subcutaneous fat around the thorax and abdomen. This inward-compressive force on the chest wall causes the diaphragm to move cephalad, resulting in the closure of the airways during tidal breathing, especially in the dependent lung zone. This is the reason for the breathlessness disproportionate to the exertion experienced by the obese patient. [13]

The maintenance of the FEV1/FVC ratio in the obese group (79.6%) in our study is in line with the results obtained by Jones et al. [14] and Santana et al. [15] This is a critical piece of information in clinical practice because it reassures us that the spirometric pattern in obesity is a restrictive rather than obstructive pattern and should not lead us to automatically administer bronchodilators unless there is independent evidence of airway obstruction. Previous studies may have inadvertently misclassified patients with restriction as having obstruction by not stratifying obese patients by spirometric pattern and relying on FEV1 percentage alone without calculating the ratio.

The significant negative correlation between BMI and FVC ($r = -0.61$) and ERV ($r = -0.67$) in the obese group is in agreement with the dose-response relationship found by Ochs-Balcom et al. [16] in a large population-based cohort, in whom each unit increase in BMI was found to cause a proportionate reduction in FVC and FEV1. Waist circumference, a marker of central obesity, had even more significant negative correlations with FVC ($r = -0.63$), emphasizing the role of central obesity in respiratory impairment. This is particularly pertinent in South Asians, such as Indians, in whom there is a known tendency to accumulate central obesity at lower levels of BMI. [17] This high prevalence of the restrictive pattern among the obese group compared to the sedentary control group in this study is similar to the observations made by Wannamethee et al. [18] and Littleton [19], wherein the authors concluded in their respective studies that obesity is an independent predictor of the restrictive spirometric pattern even after adjusting for smoking and age. Moreover, the fact that 10% of the obese population exhibited severe restriction with FVC < 50% predicted highlights the level of subclinical disease among the obese population, emphasizing the need for routine spirometric tests among the obese.

In the sedentary non-obese group, the spirometric parameters were found to be average and within normal limits but were somewhat reduced compared to published normative data, thereby supporting the hypothesis that sedentary lifestyle per se may lead to suboptimally conditioned inspiratory and expiratory muscles and reduced thoracic excursion. The decrease in FEF25-75% in the sedentary group may also be due to small airway dysfunction due to impaired collateral ventilation and low-grade inflammation associated with a sedentary lifestyle, as postulated by Ferretti et al. [20]

The inflammatory dimension of the mechanical model of obesity-related lung dysfunction, which includes the upregulation of leptin, IL-6, and CRP and their direct bronchoconstrictive and airway remodeling effects, could not be quantified in this study but is an important pathway that needs to be considered in the future to formulate a comprehensive model of the interaction between obesity and the lungs. The strength of the study lies in the well-matched control group, the use of the ATS/ERS spirometric standards, the use of India-specific ICMR reference values, and the comprehensive assessment of various spirometric values including accessory lung volumes. The limitation of the study lies in the cross-sectional design that does not support causality, the lack of measurement of TLC and RV by the plethysmographic method, which would have more definitely confirmed the restrictive pattern, and the small sample size from an urban center only.

Conclusion

Obesity also affects pulmonary function significantly, resulting in restrictive ventilatory dysfunction with reduced FVC, FEV1, ERV, PEFR, and FEF25-75%, while the FEV1/FVC ratio is normal. BMI and WC show strong negative correlations with various spirometric indices; the strongest correlation is found with ERV. Restrictive spirometric dysfunction is observed in more than half of the obese population, with severe restrictive dysfunction observed in 10%. This

highlights the subclinical respiratory dysfunction associated with obesity. The above findings make a strong case for the routine assessment of respiratory function in the overall management of obesity by including spirometry in the routine assessment of obese patients.

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