Section: Miscellaneous

Original Research Article

CORRELATION BETWEEN HRCT PARAMETER OF COPD AND SEVERITY OF DISEASE BY USING BODE INDEX AMONG COPD PATIENTS

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Received : 12/04/2025
Received in revised form : 31/05/2025
Accepted : 18/06/2025

Keywords:
COPD, HRCT, BODE Index, Airway Wall Thickness, Disease Severity.

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DOI: 10.47009/jamp.2025.7.3.210

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2025; 7 (3); 1096-1101

Abstract

Background: Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory disorder characterized by airflow limitation and structural lung changes. High-Resolution Computed Tomography (HRCT) provides detailed visualization of lung architecture, while the BODE Index—incorporating Body Mass Index (B), degree of airflow Obstruction (O), Dyspnea (D), and Exercise capacity (E)—is a multidimensional tool to assess disease severity and predict prognosis. This study aims to evaluate the correlation between HRCT parameters and disease severity as measured by the BODE Index in COPD patients. **Material and Methods:** A prospective observationa study was carried out in Department of Medicine on 110 diagnosed COPD patients. HRCT scans were performed to assess key parameters like tracheal index, saber sheath trachea, stereo-aortic distance, thoracic cross-sectional area, thoracic cage ratio, vascular attenuation. BODE Index scores were calculated for each patient based on BMI, FEV_1 (% predicted), mMRC dyspnea scale, and 6-minute walk distance (6MWD). Statistical analysis using Pearson's correlation and multivariate regression was employed to determine associations between HRCT findings and BODE Index components. **Results:** Significant positive correlations were observed between HRCT-derived and BODE Index ($r = 0.64$, $p < 0.001$), particularly with FEV_1 and 6MWD components. Airway wall thickness was moderately associated with increased dyspnea and lower exercise capacity ($p < 0.01$). Patients with higher BODE scores demonstrated more severe structural changes on HRCT, suggesting a direct relationship between imaging findings and clinical severity. **Conclusion:** HRCT parameters, particularly airway remodeling, show strong correlation with BODE Index in COPD patients, highlighting their utility as non-invasive predictors of disease severity. Integrating HRCT assessment with clinical indices like BODE enhances the understanding of COPD progression and aids in comprehensive patient management and prognostication.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a chronic, progressive respiratory condition characterized by persistent airflow limitation and an abnormal inflammatory response of the lungs to harmful particles and gases, most notably from cigarette smoking.[1] Encompassing both chronic bronchitis and emphysema, COPD is marked by symptoms such as chronic cough, dyspnea, and sputum production, significantly impairing patients' quality of life (QoL) and contributing to substantial healthcare burdens globally.[2] The World Health Organization (WHO) projects that by 2030, COPD will become the third leading cause of death worldwide, underscoring the urgent need for improved diagnostic and prognostic strategies.[3]
Effective COPD management aims to alleviate symptoms, slow disease progression, and enhance functional capacity. Traditional assessment relies on

ISSN (O): 2687-5365; ISSN (P): 2753-6556

spirometry, particularly the Forced Expiratory Volume in 1 second (FEV_1), which forms the basis of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification.[4] However, spirometry alone fails to capture the full spectrum of structural lung abnormalities associated with disease progression. In this context, imaging modalities, especially High-Resolution Computed Tomography (HRCT), have emerged as critical tools in the comprehensive evaluation of COPD.[5]

HRCT offers high-detail visualization of pulmonary structures and can detect emphysematous changes, airway remodeling, and vascular alterations not evident on chest radiographs or through spirometry.[6] Quantitative HRCT parameters—such as Tracheal Index (TI), Saber Sheath Trachea (SST), Thoracic Cage Ratio (TCR), Thoracic Cross-Sectional Area (TCSA), and Vascular Attenuation—have shown promise as objective markers of disease severity.[7-9] These parameters can reflect underlying pathological changes and correlate with functional limitations in COPD patients.

In parallel, the BODE Index—a multidimensional scoring system incorporating Body Mass Index (BMI), airflow Obstruction (FEV_1), Dyspnea (mMRC scale), and Exercise capacity (6-minute walk test)—provides a more holistic assessment of COPD severity and prognosis.[10] Unlike spirometry alone, the BODE Index captures the systemic and functional consequences of COPD, making it a superior tool for risk stratification and outcome prediction.

Aim of the Study: Given the importance of structural changes in COPD and the role of the BODE index in assessing disease severity. To assess the HRCT parameters in COPD patients. To correlate various HRCT Parameters with BODE index in COPD patients.

MATERIAL AND METHODS

Study Design and Setting- A hospital-based cross-sectional study was carried out in the Department of Medicine, Shyam Shah Medical College and associated Sanjay Gandhi Memorial Hospital, Rewa (M.P.), from September 2023 to August 2024. The study aimed to evaluate the correlation between high-resolution computed tomography (HRCT) parameters and the severity of COPD using the BODE Index.

Study Population and Sample Size- Clinically stable patients aged ≥40 years, diagnosed with COPD according to GOLD criteria (post-bronchodilator $FEV_1/FVC < 0.70$ or FEV_1 <80% predicted), were included after informed consent. Exclusion criteria included acute exacerbation, other chronic lung diseases, significant comorbidities, or inability to undergo HRCT or spirometry. Based on a 7.4% COPD prevalence the calculated sample size was 110.

Inclusion Criteria

- Patients aged 40 years and above.
- Diagnosed cases of COPD based on spirometric findings (post-bronchodilator FEV1/FVC ratio < 0.70 OR FEV1<80% predicted).
- Patients willing to provide informed consent.

Exclusion Criteria

- Patients with acute exacerbation of COPD at the time of evaluation.
- History of other significant respiratory diseases (e.g., bronchiectasis, pulmonary fibrosis, or lung cancer).
- Presence of significant cardiovascular or musculoskeletal conditions affecting exercise capacity.
- Inability to perform HRCT or pulmonary function tests (PFTs).

Spirometry and BODE Index Assessment- Spirometry was performed using a Medisoft body box plethysmograph, adhering to ATS/ERS guidelines. Measurements included FEV_1, FVC, FEV_1/FVC, PEFR, and bronchodilator reversibility. The BODE Index was calculated based on:

- Body Mass Index (BMI)
- Airflow obstruction (FEV_1 % predicted)
- Dyspnea (mMRC scale)
- Exercise capacity (6-minute walk distance)

HRCT Evaluation- HRCT scans were performed using a GE Revolution 128-slice CT scanner, with 1 mm collimation, 120 kVp, and 90 mA, during full inspiration in the supine position. Radiologists, blinded to spirometry and BODE scores, evaluated parameters including tracheal index (TI), saber sheath trachea (SST), thoracic cage ratio (TCR), thoracic cross-sectional area (TCSA), and vascular attenuation (VA).

MMRC DYSPNEA SCALE[11]

Grade 0 -No dyspnea/ only on severe exertion

Grade 1 -Dyspnea on hurrying/ walking up a hill

Grade 2-Walks slower than normal at level/ pause while walking on level Ground

Grade 3- Stops for breath after walking 100 yards /few mins on level

Grade 4-Too breathless to leave the house/ dyspnea on dressing

BODE INDEX VALUE[12,13]

VARIABLE	0	1	2	3
FEV1(% of predicted)	≥65	50-64	36-49	≤35
Distance walked in 6 min(m)	≥350	250-349	150-249	≤149
Medical Research Council dyspnea Scale score (0-4)	0-1	2	3	4
Body mass index	>21	≤21	-	`-

Data Collection and Statistical Analysis- Demographic, clinical, spirometric, HRCT, and BODE data were recorded and analyzed using appropriate statistical software. Continuous variables were presented as mean ± SD;

ISSN (O): 2687-5365; ISSN (P): 2753-6556

categorical variables as frequencies and percentages. Pearson or Spearman correlation coefficients assessed relationships between HRCT and BODE Index components. Multiple regression identified predictors of COPD severity.

RESULTS

Table 1: Demographic distribution of COPD patients

Age Group (in years)	Number of Cases	Percentage
40-50 Years	04	3.64
51-60 Years	26	23.64
61-70 Years	54	49.09
>70 Years	26	23.64
Gender		
Male	72	65.45
Female	38	34.55
Occupation		
Farmer	53	48.18
Housewife	38	34.55
Businessman	10	9.09
Laborer	5	4.54
Others	4	3.63

The majority of patients in the study were aged between 61–70 years (49.09%), followed by those aged above 70 and 51–60 years (23.64% each). Males comprised 65.45% of the study population. Most patients were farmers (48.18%), followed by housewives (34.55%), with smaller proportions engaged in business, labor, or other occupations. (Table1)

Table 2: Clinical finding of COPD patients

mMRC Scale Grade	No of cases	Percentage
Grade I	01	0.91
Grade II	34	30.91
Grade III	48	43.64
Grade IV	27	24.55
BODE index		
Mild (0-2)	13	11.82
Moderate (3-5)	43	39.09
Severe (≥6)	54	49.09

Most patients in the study had Grade III dyspnea on the mMRC scale (43.64%), followed by Grade II (30.91%) and Grade IV (24.55%), while only one patient had Grade I symptoms. Based on the BODE Index, 49.09% of cases were classified as severe, 39.09% as moderate, and 11.82% as mild. (Table 2)

Table 3: COPD patients in correlation with different parameters according to Severity of BODE Index

BODE index	Mean ±SD value of height in cm	Correlation (r)	P value
Mild (0-2) (n=13)	158.38±1.50	0.63	0.021 S
Moderate (3-5) (n=43)	157.86±2.07	0.15	0.337 NS
Severe (≥6) (n=54)	158.70±2.68	0.16	0.247 NS
FEV1			
Mild (0-2) (n=13)	79.23±1.30	0.24	0.429 NS
Moderate (3-5) (n=43)	58.14±8.35	0.91	0.0001 HS
Severe (≥6) (n=54)	43.24±8.18	0.31	0.022 S
Tracheal Index (1 c.m. Above Aortic Arch)			
Mild (0-2) (n=13)	0.79±0.02	0.05	0.871 NS
Moderate (3-5) (n=43)	0.72±0.05	0.45	0.002 S
Severe (≥6) (n=54)	0.66±0.04	0.51	0.001 S
Sterno-Aortic Distance SAD (At Carina Level)			
Mild (0-2) (n=13)	30.98±11.55	0.09	0.770 NS
Moderate (3-5) (n=43)	34.10±2.87	0.55	0.0001 HS
Severe (≥6) (n=54)	40.64±3.55	0.34	0.011 S
Sterno Aortic Distance SAD (At Carina Level) to BMI			
<18.0 (n=17)	43.15±4.58	0.34	0.181 NS
18-24.9 (n=88)	39.41±5.16	0.70	0.0001 HS
>24.9 (n=5)	32.20±2.17	0.56	0.011 S
Thoracic cross-sectional Area (1 c.m. Below Top of Aortic Arch)			
Mild (0-2) (n=13)	229.96±49.25	0.13	0.672 NS
Moderate (3-5) (n=43)	254.16±18.50	0.74	0.0001 HS
Severe (≥6) (n=54)	272.09±24.32	0.63	0.0001 HS
Thoracic Cage Ratio (At level of carina)			
Mild (0-2) (n=13)	0.66±0.12	0.22	0.0943 NS
Moderate (3-5) (n=43)	0.68±0.09	0.65	0.0001 S
Severe (≥6) (n=54)	0.72±0.04	0.45	0.0003 S

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Vascular Attenuation			
Mild (0-2) (n=13)	27.17+0.28	0.133	0.664 NS
Moderate (3-5) (n=43)	32.64+3.38	0.67	0.0001 S
Severe (≥6) (n=54)	29.69+2.49	0.44	0.0009 S

The study analyzed correlations between BODE index severity and various clinical and radiological parameters. Height showed a significant positive correlation only in the mild group ($r = 0.63$, $p = 0.021$). FEV1 had a highly significant and positive correlation in the moderate group ($r = 0.91$, $p < 0.0001$) and severe group ($r = 0.31$, $p = 0.022$). Tracheal index and sterno-aortic distance (SAD) significantly correlated with BODE severity in moderate and severe groups, suggesting increased airway changes with disease progression. SAD also showed a significant correlation with BMI categories, especially in the normal (18–24.9) and overweight (>24.9) ranges. Thoracic cross-sectional area and thoracic cage ratio demonstrated strong positive correlations in moderate and severe groups, reflecting structural lung changes. Vascular attenuation also significantly correlated with BODE severity in these groups, indicating vascular remodeling. Overall, HRCT parameters showed progressively stronger correlations with increasing COPD severity. (Table 3)

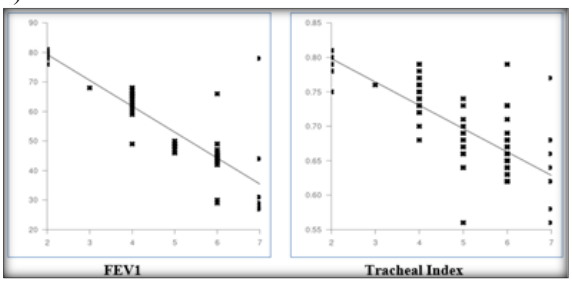

Figure 1: Graph shows Linear Regression of different parameters to Severity of BODE Index

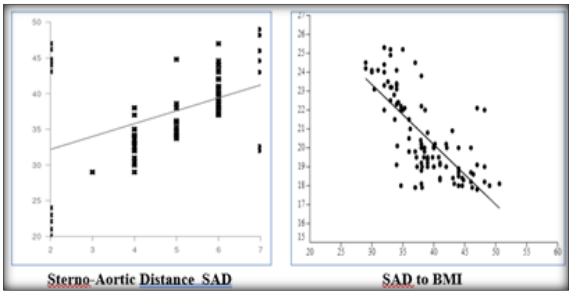

Figure 2

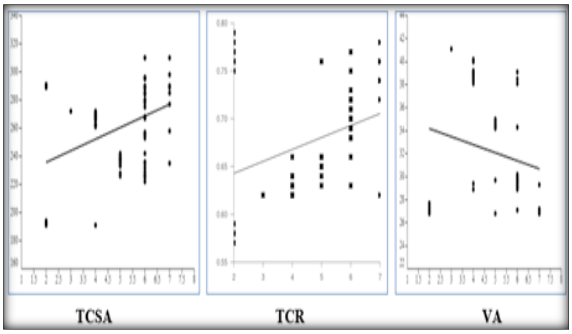

Figure 3

DISCUSSION

The integration of High-Resolution Computed Tomography (HRCT) parameters with the Body Mass Index, Airflow Obstruction, Dyspnea, and Exercise Capacity (BODE) Index offers a comprehensive approach to assessing Chronic Obstructive Pulmonary Disease (COPD) severity. Our study evaluated correlations between HRCT-derived metrics and BODE Index scores among COPD patients.

In the mild BODE group (scores 0–2), height exhibited a significant positive correlation ($r = 0.63$, $p = 0.021$). However, this correlation diminished in moderate and severe groups, indicating that anthropometric factors may have limited influence as disease severity escalates. Forced Expiratory Volume in 1 second (FEV_1) demonstrated a robust positive correlation in the moderate group ($r = 0.91$, $p < 0.0001$) and a moderate correlation in the severe group ($r = 0.31$, $p = 0.022$), underscoring its relevance in assessing airflow obstruction across disease stages. Singh et al. (2021) they found that among the components of the BODE index, a decrease in FEV_1 (% predicted) was associated with worsening health status, as measured by the St. George's Respiratory Questionnaire (SGRQ). This indicates that FEV_1 is a significant factor in assessing disease severity and its impact on HRQoL in COPD patients.[14] Sarkar et al. (2015) they reported that higher BODE quartiles were associated with higher total SGRQ scores and subscale scores (symptom, activity, and impact). Although the study emphasized the BODE index's superiority over the GOLD classification in reflecting health status, it also highlighted the role of FEV_1 as a component influencing the BODE index and, consequently, HRQoL.[15]

The Tracheal Index (TI) at 1 cm above Aortic Arch level showed significant negative correlations in moderate ($r = 0.45$, $p = 0.002$) and severe ($r = 0.51$, $p = 0.001$) BODE groups, suggesting progressive tracheal narrowing with disease advancement. This aligns with findings by Bhaskar et al. (2018),[16] who reported a decreasing TI correlating with increasing COPD severity. Eom et al. (2013) investigated the relationship between the tracheal index (TI) and lung volume parameters in patients with mild-to-moderate COPD. They found that TI was significantly reduced in COPD patients compared to controls and that TI had inverse correlations with total lung capacity, functional residual capacity, and residual volume.[17] Ciccarese et al. (2014) they reported that a decreased TI was associated with more severe airflow limitation and that the presence of saber-sheath trachea correlated with higher GOLD stages.[18] Gallardo Estrella et al. (2017) they found that tracheal morphological changes, including a reduced TI, were

ISSN (O): 2687-5365; ISSN (P): 2753-6556

associated with increased airflow obstruction and that these changes could be quantified to assess disease severity.[19] The tracheal index and presence of saber sheath trachea, both indicative of tracheal deformity and airway collapse, were also significantly associated with higher BODE scores. These findings underscore the importance of central airway changes in the pathophysiology of advanced COPD.

Sterno-Aortic Distance (SAD) at the carina level representing the anteroposterior space between the posterior aspect of the sternum and the ascending aorta. SAD correlated significantly with BODE scores in moderate ($r = 0.55$, $p < 0.0001$) and severe ($r = 0.34$, $p = 0.011$) groups, indicating thoracic structural changes associated with disease progression This moderate positive correlation indicates that as the SAD increases, the severity of disease as measured by the BODE Index also increases. It is particularly relevant in distinguishing patients with predominantly emphysematous pathology versus those with airway-dominant disease.

Notably, SAD also correlated with Body Mass Index (BMI), particularly in the 18–24.9 kg/m² category ($r = 0.70$, $p < 0.0001$), reflecting the interplay between nutritional status and thoracic anatomy.

The anatomical shift of mediastinal structures in severe emphysema cases has been previously documented (Yamada et al., 2012), and our results reinforce the utility of SAD as a surrogate marker of hyperinflation.˙ Kalyani et al. (2023) they found that the BODE index was significantly associated with nutritional status, as indicated by changes in BMI status. Specifically, severe COPD cases exhibited higher CRP levels and lower hemoglobin levels, indicating systemic inflammation and nutritional depletion. Hypermetabolic and catabolic state, contributing to unintentional weight loss and reduced BMI. Muscle Wasting and Diaphragmatic Dysfunction: Hyperinflation also leads to diaphragmatic flattening and reduced mechanical advantage, which increases energy cost for breathing and contributes to peripheral muscle deconditioning. These findings support the association between increased SAD and higher BODE index scores, reflecting disease severity.[21]

Thoracic Cross-Sectional Area (TCSA) measured 1 cm below the top of the aortic arch exhibited strong positive correlations in moderate ($r = 0.74$, $p < 0.0001$) and severe ($r = 0.63$, $p < 0.0001$) BODE groups. Thoracic cross-sectional area and sterno-aortic distance, while not as strongly correlated, still provided valuable information about thoracic dimensional changes and anterior mediastinal displacement. These features may further help in phenotyping patients with predominant emphysematous or hyperinflated lung patterns.

The Thoracic Cage Ratio at the carina level correlated significantly in moderate ($r = 0.65$, $p < 0.0001$) and severe ($r = 0.45$, $p = 0.0003$) groups, indicating hyperinflation and structural remodeling as COPD progresses. These findings are consistent with Jain et al. (2017),[22] who emphasized the significance of quantitative radiological phenotypes in COPD and their correlation with the BODE Index. The thoracic cage ratio, indicative of hyperinflation and altered chest wall mechanics, also showed a significant positive correlation with BODE Index. Increased anteroposterior diameter is a hallmark of hyperinflated lungs and reflects compensatory changes in thoracic architecture. This is often associated with diaphragmatic flattening and reduced mechanical efficiency, contributing to exertional breathlessness and reduced exercise tolerance.

This supports the hypothesis that thoracic enlargement corresponds to parenchymal destruction and air trapping, consistent with findings by Kubo et al. (2015), who demonstrated that thoracic CSA increases in emphysematous COPD phenotypes.[23]

Vascular attenuation, indicative of pulmonary vascular changes, showed significant correlations in moderate ($r = 0.67$, $p < 0.0001$) and severe ($r = 0.44$, $p = 0.0009$) BODE groups. This suggests that vascular remodeling is a pertinent feature in advanced COPD stages. Vascular attenuation reflects the extent of pulmonary vascular remodeling and destruction due to emphysema. Reduced vascular markings on HRCT correlate with diminished pulmonary perfusion and impaired gas exchange, aligning with lower exercise capacity and greater dyspnea scores in the BODE Index. These findings are consistent with previous studies highlighting the utility of vascular pruning as an imaging biomarker for emphysema severity.

Among these parameters, vascular attenuation and thoracic cage ratio showed the strongest positive correlation with higher BODE scores, highlighting their potential as imaging markers of disease severity, particularly in emphysema-dominant phenotypes. The tracheal index and presence of saber sheath trachea reflected central airway remodeling, which also correlated with increasing disease burden. Sterno-aortic distance showed a moderate correlation with both BODE Index and BMI, suggesting a link between hyperinflation and systemic effects like weight loss.

CONCLUSION

Collectively, these correlations underscore the utility of integrating HRCT parameters in conjunction with the BODE Index to provide a multidimensional assessment of COPD severity. Such integrative approaches can enhance early diagnosis, prognostication, risk stratification and guide personalized management strategies for COPD patients. This study may be useful to provide anatomical details, in patients with effort dependent pathology, localise pathology, distinguish phenotypes and detect comorbid structural changes.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

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ISSN (O): 2687-5365; ISSN (P): 2753-6556