Section: Pulmonary Medicine

Original Research Article

STUDY OF BODE INDEX AND CPET FINDINGS IN PATIENTS WITH STABLE COPD

Ishani Deshmukh[1], Pinkutty Sagar[2], Priti L. Meshram[3], Sameer Vaidya[4], Pramod Chavan[5]

[1]*Associate Professor, Department of Pulmonary Medicine, Index Medical College and Research Institute, Indore, India.*
[2]*Assistant Professor, Department of Pulmonary Medicine, Pondicherry Institute of Medical Sciences, Pondicherry, India.*
[3]*Professor and Head, Department of Pulmonary Medicine, Grant Medical College Mumbai, India.*
[4]*Assistant Professor, Index Medical College and Research Institute Indore, India.*
[5]*Consultant, Department of Pulmonary Medicine, Saijyot Multispeciality Hospital, Navi Mumbai, India.*

Received *: 22/08/2025*
Received in revised form *: 07/10/2025*
Accepted *: 28/10/2025*

Corresponding Author:
Dr. Pinkutty Sagar
Assistant Professor, Department of Pulmonary Medicine, Pondicherry Institute of Medical Sciences, Pondicherry, India.
Email: pinkuttysagar@gmail.com

DOI:10.70034/ijmedph.2025.4.214

Source of Support: Nil,
Conflict of Interest: Nonedeclared

Int J Med Pub Health
2025; 15 (4); 1191-1198

ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) is a progressive systemic illness characterized by airflow limitation and reduced exercise capacity. The BODE index (Body mass index, degree of airflow Obstruction, Dyspnea, and Exercise capacity) is a multidimensional tool for prognostication, while Cardiopulmonary Exercise Testing (CPET) provides an objective assessment of functional capacity. This study aimed to evaluate the relationship between BODE index and CPET parameters in patients with stable COPD.

Materials and Methods: This prospective observational study was conducted in the Department of Pulmonary Medicine of a tertiary care hospital in India on 50 stable COPD patients aged over 18 years. Detailed history, clinical examination, spirometry, 6-minute walk test (6MWT), and CPET using a cycle ergometer were performed. BODE scores were calculated for each patient, and severity was classified based on GOLD guidelines. CPET parameters including VO_2max (% predicted), Anaerobic Threshold (AT) at VO_2max (%), and Metabolic Equivalents of Task (METS) were measured. Correlations between BODE score, GOLD classification, and CPET parameters were analyzed using Spearman's rank correlation.

Results: The study included 42 males (84%) and 8 females (16%) with a mean age of 56.8 ± 14.1 years. Most participants (84%) had BODE scores <5 and belonged to GOLD group A (54%). The mean VO_2 max was 28.21% of the predicted value (SD = 5.47) which was reduced. The mean anaerobic threshold (AT) at VO_2 max was 58.76% with a relatively higher variability (SD = 21.17), reflecting inter-individual differences in exercise tolerance. The mean metabolic equivalents (METS) achieved during CPET were 4.98 (SD = 1.47), further supporting the presence of limited functional capacity. VO_2max and AT at VO_2max showed no significant correlation with BODE or GOLD groups. However, METS showed a significant negative correlation with both BODE ($r = -0.325$, $p < 0.05$) and GOLD groups ($r = -0.398$, $p < 0.05$). Leg pain as a reason for exercise termination predominated in patients with lower BODE scores and GOLD group A.

Conclusion: The study showed that there was significant functional impairment in COPD even in early disease. METS is a sensitive marker of functional impairment. COPD is a systemic disease and exercise limitation in COPD is of multifactorial etiology. In addition to respiratory limitation other cardiovascular and musculoskeletal comorbidities also contribute to the exercise limitation and should be sought and managed.

Keywords: Chronic Obstructive Pulmonary Disease (COPD); BODE index; Cardiopulmonary Exercise Testing (CPET); Exercise capacity; METS.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD), as defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD), is a heterogenous lung condition characterised by chronic respiratory conditions (dyspnoea/ cough /sputum production and / or exacerbation) due to abnormalities of airway and/or alveoli that cause persistent often progressive airflow obstruction.[1] COPD remains a major cause of chronic morbidity and mortality worldwide and represents a significant public health challenge. It is currently the fourth leading cause of death globally.[2] The global burden of COPD is expected to continue rising in the coming decades, largely due to persistent exposure to major risk factors such as tobacco smoke, biomass fuel exposure, and air pollution, coupled with the progressive aging of populations worldwide.[3] This growing burden highlights the pressing need for early diagnosis, accurate prognosis, and effective disease management strategies.

The clinical course of COPD is often characterized by progressive airflow obstruction, recurrent exacerbations, declining physical capacity, and worsening quality of life. While spirometry remains the gold standard for diagnosing airflow limitation, it provides limited information on disease prognosis or extrapulmonary manifestations. Given this limitation, there has been growing interest in using multidimensional indices that integrate various clinical and physiological factors to predict outcomes more accurately. One such tool is the BODE index—a composite scoring system that includes Body Mass Index (B), the degree of airflow Obstruction (O), Dyspnea (D), and Exercise capacity (E).[4] This multidimensional 10-point scale has been shown to correlate well with mortality risk, disease severity, and hospitalization rates in COPD.[5] The BODE index has been validated across different patient populations and care settings, including both specialized pulmonary clinics and primary care, and has been found to be a robust predictor of future exacerbations and health-related quality of life.[5] Importantly, it accounts for both pulmonary and extrapulmonary factors, thereby offering a more comprehensive assessment of disease burden and survival prospects than spirometry alone.

Exercise intolerance is a hallmark feature of COPD and often emerges even in the early stages of the disease.[6] Although exertional symptoms may be mild initially, progressive exercise limitation becomes one of the most disabling and distressing consequences of COPD for most patients. Traditionally, the objective assessment of disease severity has relied predominantly on pulmonary function tests (PFTs) performed at rest. However, PFTs cannot fully capture the complexity of exercise intolerance, which results from the integrated influence of several physiological factors, including pulmonary mechanics, ventilation-perfusion mismatch, pulmonary circulation abnormalities, cardiac dysfunction, peripheral muscle weakness, metabolic derangements, and psychological factors. The interaction of these factors ultimately determines the functional capacity of an individual patient.

To address this gap, various exercise tests have been employed to assess functional performance in COPD patients. These include stair climbing tests, six-minute walk tests, shuttle walk tests, and cardiac stress tests. While these tests differ in terms of reproducibility, cost, and the type of information they provide, cardiopulmonary exercise testing (CPET) has emerged as the most comprehensive and informative method. CPET offers an integrated assessment of the physiological responses to exercise, simultaneously evaluating the function of the pulmonary, cardiovascular, hematopoietic, neuromuscular, and skeletal muscle systems. Unlike the six-minute walk distance, which merely reflects functional capacity, CPET provides detailed insights into the underlying mechanisms of exercise limitation. One of the key parameters derived from CPET is maximal oxygen uptake (VO_2 max), which reflects the severity of functional impairment and correlates more strongly with symptoms and disease severity than resting PFTs. Resting measurements cannot reliably predict exercise performance or exercise-induced hypoxemia, whereas CPET can objectively quantify these deficits.

Given its ability to accurately assess both disease severity and exercise capacity, CPET has increasing clinical relevance in guiding exercise prescription, evaluating response to therapy, and stratifying risk in COPD patients. With the recognition that overall health status correlates more closely with exercise tolerance than with resting pulmonary function, the incorporation of CPET into COPD management is gaining momentum.(7) Against this background, the present prospective study was designed to evaluate the correlation between the BODE index and CPET-derived parameters in stable COPD patients. Establishing this relationship could enhance prognostic assessment and support more personalized therapeutic strategies in this patient population.

MATERIALS AND METHODS

This prospective observational study was conducted in the Cardiopulmonary Exercise Testing (CPET) unit of the Department of Pulmonary Medicine at a tertiary care public hospital inMumbai, India, after taking approval from the Institutional ethics committee. A total of 50stable Chronic Obstructive Pulmonary Disease (COPD) adult patients of both the genders were recruited from the outpatient services of the Pulmonary Medicine Department, after taking their written informed consent. Patients with COPD exacerbation, active infection, cardiac

comorbities, renal failure, neurological or locomotor disorders were excluded. COPD was diagnosed as per GOLD guidelines. The spirometry was performed for all the subjectson a computerized Pulmonary Function Test system (Medigraphics Cardiorespiratory Diagnostics) and was interpreted as per the American Thoracic Society (ATS) guidelines. Forced vital capacity (FVC), forced expiratory volume at 1 second (FEV_1), FEV_1/FVC ratio were recorded. The patients were divided in 4 stages as per GOLD staging based on post bronchodilator FEV1and Groups A,B and E .

- GOLD 1 (Mild): $FEV_1/FVC < 0.70$ and $FEV_1 \geq 80\%$ predicted
- GOLD 2 (Moderate): $FEV_1/FVC < 0.70$ and $50\% \leq FEV_1 < 80\%$ predicted
- GOLD 3 (Severe): $FEV_1/FVC < 0.70$ and $30\% \leq FEV_1 < 50\%$ predicted
- GOLD 4 (Very severe): $FEV_1/FVC < 0.70$ and $FEV_1 < 30\%$ predicted

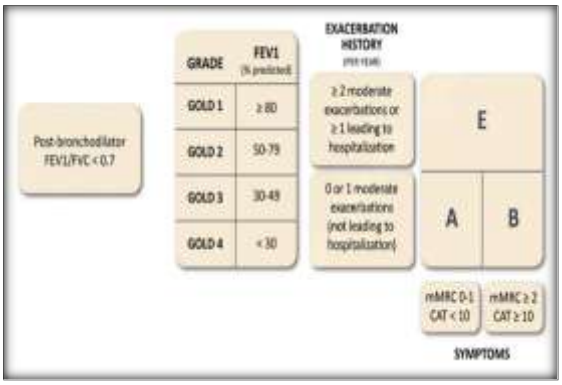

Figure 1

Respiratory symptoms such as cough, breathlessness, wheeze, chest pain, and other systemic complaints were recorded. The severity of dyspnea was graded using the Modified Medical Research Council (mMRC) Dyspnea Scale. The number of COPD exacerbations and related hospitalizations in the preceding year was documented. Exercise tolerance was assessed by the Six-Minute Walk Test according to ATS guidelines. Pre-test vital signs (arterial oxygen saturation, pulse rate, and blood pressure) and baseline symptoms of dyspnea and fatigue (Borg scale) were recorded. The test was terminated if severe desaturation, chest pain, syncope, or other distressing symptoms occurred. The total distance walked was recorded, and symptoms were reassessed immediately post-test. CPET was conducted using a Medigraphics CPX Ultima Cardiorespiratory Analysis System in accordance with the ATS/ACCP Statement on Cardiopulmonary Exercise Testing. The tests were conducted under continuous supervision of a chest physician with well-defined safety termination criteria.

A properly fitted preVent mask was applied, and the gas analyzer was autocalibrated. Continuous ECG monitoring was done using a standard 12-lead system. Arterial oxygen saturation and heart rate were continuously recorded via pulse oximetry. Blood pressure was measured at rest, at VO_2max, and at five minutes into recovery using an automated sphygmomanometer. CPET was performed on a cycle ergometer using a symptom-limited incremental RAMP protocol. After a two-minute rest period, participants performed unloaded cycling at 45–60 RPM for three minutes, followed by incremental workload increases until symptom limitation. Standardized encouragement was given throughout the test. The test was terminated on development of any of the following: ischemic chest pain or ECG changes, complex arrhythmias, second- or third-degree heart block, fall in systolic blood pressure >20 mmHg from peak or below resting, severe hypertension (>250/120 mmHg), severe desaturation (SpO_2 <80% with symptoms), sudden pallor, loss of coordination, dizziness, signs of respiratory failure, mental confusion, or at patient's request due to extreme dyspnea, chest pain, or leg discomfort. The reason for termination was documented. Patients were monitored until they were hemodynamically stable and had returned to baseline. CPET was conducted using a Medigraphics CPX Ultima Cardiorespiratory Analysis System.

CPET parameters studied:

1) Maximal oxygen uptake (VO_2max) is the oxygen uptake attained during maximal exercise intensity that could not be increased despite further increases in exercise workload, thereby defining the limits of the cardiorespiratory system. This reflects the maximal ability of a person to take in, transport and use oxygen. It defines that person's functional aerobic capacity
2) Anerobic threshold (AT)% expressed in terms of VO2max (as percentage) is a point during exercise when the energy demands of the exercising muscles exceed the body's ability to produce energy by aerobic metabolism, signalled by rise in lactate levels. Patients who have cardiac disease often reach their AT at a lower workload (VO_2), when the demands of exercising muscles exceed the capacity of the heart to supply O_2. Patients who have a ventilatory limitation to exercise (i.e., pulmonary disease) may be unable to exercise at a high enough workload to reach their anaerobic threshold since the O_2 delivery is limited by the lungs, rather than by cardiac output or extraction by the exercising muscle. Deconditioning may be present when the AT occurs at a lower than expected workload and there is no evidence of cardiovascular disease.
3) Metabolic Equivalents of Task (METS) is a commonly used term to describe the level of work performed during an exercise evaluation or in relation to activities of daily living. One MET equals the O_2 uptake at rest. (or 3.5ml /kg/min). Maximum METS level achieved

during exercise is an index of functional capacity and exercise tolerance

BODE Index Calculation

BODE index combines four important variables into a single score: (B) body mass index; (O) airflow obstruction measured by the forced expiratory volume in one second (FEV1); (D) dyspnea measured by the modified Medical Research Council (mMRC) scale; and (E) exercise capacity measured by the 6 minute walk distance (6MWD). Each component is graded and a score out of 10 is obtained, with higher scores indicating greater risk

Table 1: BODE index calculation

Variable	0	1	2	3
FEV1(%pred)	>65	50-64	36-49	<=35
Dyspnea (mMRC grade)	0-1	2	3	4
6MWD (m)	>=350	250-349	150-249	<=149
BMI	>21	<=21		

Points from each variable are added according to the threshold value measured for each one. The value ranges from 0 to a maximum of 10.

Statistical Analysis

All data were entered in Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 26. Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Pearson's correlation coefficient was used to assess the correlation between BODE index and CPET-derived parameters (including VO_2max). The strength and direction of associations were interpreted based on correlation values. Comparisons between groups were done using Student's t-test or Chi-square test as appropriate. A p-value of <0.05 was considered statistically significant.

RESULTS

In the present study involving 50 patients with chronic obstructive pulmonary disease (COPD), the majority were males (84%), while females constituted 16% of the study population. Most participants belonged to the older age groups, with 54% aged between 61–80 years, followed by 34% in the 41–60 years group and 12% in the 20–40 years group, indicating a higher burden of COPD among older adults. Symptomatically, dyspnea was the most common presenting complaint, reported by all patients, with 84% presenting with a combination of dyspnea and cough, 14% with dyspnea alone, and only 2% with dyspnea associated with chest pain. This distribution reflects the typical demographic and clinical profile observed in COPD patients, with a male predominance, older age of onset, and dyspnea as the leading symptom. (Table 2)

Table 2: Baseline Characteristics of Study Population (n = 50)

Characteristic	Category	Number of Patients	Percentage (%)
Gender	Male	42	84
	Female	8	16
Age group (years)	20–40	6	12
	41–60	17	34
	61–80	27	54
Symptoms	Only Dyspnea	7	14
	Dyspnea and Cough	42	84
	Dyspnea and Chest Pain	1	2

Among the 50 COPD patients studied, the majority (84%) were classified as having mMRC grade 1 dyspnea, while 14% had grade 2 and only 2% had grade 3 dyspnea, indicating that most participants had mild exertional symptoms. Analysis of BODE scores showed that 84% of patients scored below 5, suggesting lower overall risk, while 14% scored between 5 and 6, and only 2% scored 7 or above, reflecting a small proportion with severe disease burden. According to GOLD classification, more than half of the patients (54%) belonged to Group A, followed by 40% in Group E, 6% in Group B.

Table 3: Distribution of Patients According to mMRC Dyspnea Grade, BODE Score, and GOLD Classification (n = 50)

Parameter	Category	Number of Patients	Percentage (%)
mMRC Dyspnea Grade	0	0	0
	1	42	84
	2	7	14
	3	1	2
	4	0	0
BODE Score	< 5	42	84
	5–6	7	14
	≥ 7	1	2
GOLD Classification	A	27	54

	B	3	6
	E	20	40

The cardiopulmonary exercise testing (CPET) parameters showed that the mean VO_2 max was 28.21% of the predicted value with a standard deviation of 5.47, indicating reduced exercise capacity among the study participants. The mean anaerobic threshold (AT) at VO_2 max was 58.76% with a relatively higher variability (SD = 21.17), reflecting inter-individual differences in exercise tolerance. The mean metabolic equivalents (METS) achieved during CPET were 4.98 (SD = 1.47), further supporting the presence of limited functional capacity. In comparison, the mean BODE score was 2.16 with a standard deviation of 1.99, suggesting that most patients had a relatively low composite risk score incorporating body mass index, airflow obstruction, dyspnea severity, and exercise capacity. (Table 4)

Table 4: Mean and Standard Deviation of CPET Parameters and BODE Score (n = 50)

Parameter	Mean	Standard Deviation
VO_2 max (% predicted)	28.21	5.47
AT at VO_2 max (%)	58.76	21.17
METS	4.98	1.47
BODE Score	2.16	1.99

Spearman's correlation analysis revealed significant relationships among BODE score, VO_2max (% predicted), anaerobic threshold (AT) at VO_2max, METS, and GOLD classification in 50 participants. The BODE score showed a strong positive correlation with GOLD classification ($\rho = 0.869$, $p < 0.001$) and a significant negative correlation with METS ($\rho = -0.325$, $p = 0.021$), indicating that increasing disease severity is associated with lower exercise capacity. VO_2max positively correlated with METS ($\rho = 0.307$, $p = 0.030$), while AT showed no significant correlations. METS also correlated negatively with GOLD classification ($\rho = -0.398$, $p = 0.004$), reflecting declining exercise tolerance with advancing disease severity. (Table 5)

Table 5: Correlation between BODE Score, VO_2max, AT at VO_2 max, METS, and GOLD Classification

	BODE score	VO_2max (% pred)	AT atVO_2max	METS	GOLD Classification
BODE score	1.000	0.089 (p=0.541)	0.154 (p=0.284)	–0.325* (p=0.021)	0.869* (p<0.001)
VO_2max (% pred)	0.089	1.000	–0.008 (p=0.956)	0.307* (p=0.030)	0.088 (p=0.543)
AT atVO_2max	0.154	–0.008	1.000	–0.185 (p=0.197)	0.057 (p=0.696)
METS	–0.325*	0.307*	–0.185	1.000	–0.398* (p=0.004)
GOLD Classification	0.869*	0.088	0.057	–0.398*	1.000

*p < 0.05 (significant)

Most common reason for termination of test was leg pain in 27 (54%) patients, followed by breathlessness in 9 (18%) patients and desaturation again in 9 (18%) patients, followed by chest pain / chest discomfort/ palpitations in 2 (4%) patients and again Blood pressure shoot in 2 (4%) patients and ECG changes in 1 (2%) patients. (Table no. 6)

Table 6: Distribution of reason for termination of test:

Sr No	Reason for termination of test	Number of patients	%
1	Leg pain	27	54
2	Breathlessness	9	18
3	Desaturation	9	18
4	Chest pain/Chest discomfort/ Palpitations	2	4
5	Blood Pressure shoot	2	4
6	ECG changes	1	2

Table 7: Correlation of BODE score and leg pain as a reason for termination of test

		Reason											
		1		2		3		4		5		6	
		Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %	Count	Row N %
BODE score	0	11	84.6%	1	7.7%	0	.0%	0	.0%	1	7.7%	0	.0%
	1	7	70.0%	2	20.0%	0	.0%	1	10.0%	0	.0%	0	.0%
	2	4	44.4%	3	33.3%	0	.0%	1	11.1%	1	11.1%	0	.0%
	3	2	40.0%	1	20.0%	2	40.0%	0	.0%	0	.0%	0	.0%
	4	2	40.0%	2	40.0%	1	20.0%	0	.0%	0	.0%	0	.0%
	5	1	25.0%	1	25.0%	2	50.0%	0	.0%	0	.0%	0	.0%
	6	0	.0%	0	.0%	2	66.7%	0	.0%	0	.0%	1	33.3%
	7	0	.0%	0	.0%	1	100.0%	0	.0%	0	.0%	0	.0%

Leg pain as a reason for termination of test was found in 11 (84.6%) patients with BODE score 0 followed by 7 (70%) patients with BODE score 1, followed by 4 (44.4%) patients with BODE score 2 followed by 2 (40%) patients with BODE score 3 and 2 (40%) patients with BODE score 4, followed by1 (25%) patients with BODE score 5. It was not the reason for termination of test in patients with BODE score 6 and 7.

Chi-Square test

Table 8:

	Value	df	P-value
Pearson Chi-Square	50.392[a]	35	.045
Likelihood Ratio	43.285	35	.159
N of Valid Cases	50		
a. 46 cells (95.8%) have expected count less than 5. The minimum expected count is .02.			

Since p-value for the chi-square is less than that of 0.05 indicates the significance of association of bode score and different reasons. It can be observed from the above table that leg pain as the reason for test termination is most common with Gold Group A. (Figure 2)

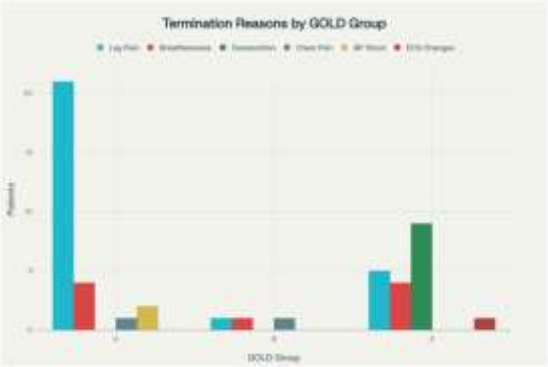

Figure 2: D Termination reasons by GOLD group

DISCUSSION

The present study titled "Study of BODE index and Cardiopulmonary Exercise Testing (CPET) parameters in patients with stable COPD" was conducted in the Department of Pulmonary Medicine and included 50 patients. Among them, 42 (84%) were males and 8 (16%) were females. In contrast, a large multicentric study by Jindal et al,[8] reported a more balanced sex distribution among 35,295 COPD patients, with 51.6% males and 48.4% females (male-to-female ratio 1.56:1). Similarly, the INSEARCH study[9] which surveyed 85,105 men and 84,470 women from 12 urban and 11 rural sites, found a prevalence of chronic bronchitis of 4.29% in men and 2.7% in women, estimating a national burden of 14.84 million. Another review by SK Jindal et al,[10] reported median prevalence rates of 5% in males and 2.7% in females, yielding a male-to-female ratio of 1.6:1, and estimating 8.15 million affected males and 4.21 million females in India (aged ≥30 years) as of 1996. The male predominance in our study may be attributed to sociocultural factors in India, where men are more likely to seek medical attention and report respiratory symptoms compared to women.

Age is an important risk factor for COPD, likely reflecting cumulative lifetime exposures. The mean age of our study participants was 56.8 ± 14.1 years, with most patients (54%) belonging to the 61–80 years age group. This finding aligns with the established understanding that COPD burden increases with age.

The cardinal symptoms of COPD are chronic and progressive dyspnea, cough, and sputum production, while wheezing and chest tightness are less specific.[1] In our study, 42 (84%) patients presented with both dyspnea and cough, 7 (14%) had dyspnea alone, and only 1 patient had both dyspnea and chest pain (Table no 2). Regarding dyspnea severity, 84% of patients had mMRC grade 1, 14% had grade 2, and 2% had grade 3, while none had grade 4(Table no 3). This lower symptom burden likely reflects the inclusion of only stable COPD patients; those with acute exacerbations or hemodynamic instability were excluded.

The mean BODE score in our study was 2.16 ± 1.99. A majority (84%) had a BODE score <5, while only one patient (2%) had a score ≥7. The BODE index is a multidimensional prognostic tool that predicts mortality in COPD patients. BODE scores ≥7, 5–6, and <5 are associated with 2-year mortalities of approximately 30%, 15%, and 10% respectively. Importantly, the BODE index has been shown to be a stronger predictor of mortality than FEV_1 alone. The low BODE scores in our cohort again reflect the inclusion of stable patients. GOLD staging showed that

The cardiopulmonary exercise testing (CPET) parameters showed that the mean VO_2 max was 28.21% of the predicted value with a standard deviation of 5.47, indicating reduced exercise capacity among the study participants. The mean anaerobic threshold (AT) at VO_2 max was 58.76% with a relatively higher variability (SD = 21.17), reflecting inter-individual differences in exercise tolerance. The mean metabolic equivalents (METS) achieved during CPET were 4.98 (SD = 1.47), further supporting the presence of limited functional capacity. We explored correlations between CPET parameters (VO_2max % predicted, anaerobic threshold [AT] at VO_2max, and METS) and disease severity indices (BODE score and GOLD group) using Spearman's rank correlation. In a similar

study, Sheetal et al,[11] observed that VO_2max correlated strongly with FEV_1, and that AT also significantly correlated with FEV_1. They noted wide variability in VO_2max at lower FEV_1 levels, suggesting that as airflow limitation worsens, other factors contribute to exercise limitation. VO_2max showed a linear negative correlation with the BODE index. Likewise, Ganju et al,[12] found a significant correlation between FEV_1% predicted and VO_2max% predicted in COPD patients across mild, moderate, and severe groups, though again there was wide variability of peak VO_2 at similar degrees of obstruction. They also reported that AT was attained in all patients, but 53.5% had low %AT (<30%), suggesting deconditioning due to sedentary lifestyle, which could improve with exercise training.

In our study, however, BODE score did not correlate significantly with VO_2max ($\rho = 0.089$, $p>0.05$) or AT atVO_2max ($\rho = 0.154$, $p>0.05$), though it showed a significant negative correlation with METS ($\rho = -0.325$, $p=0.021$). GOLD grouping showed no significant correlation with VO_2max ($\rho = 0.088$, $p>0.05$) or AT at VO_2max ($\rho = 0.057$, $p>0.05$), but had a significant negative correlation with METS ($\rho = -0.398$, $p=0.004$). This suggests that while METS reflects functional limitation, VO_2max and AT may be influenced by multifactorial contributors beyond respiratory impairment in stable COPD.

These findings reinforce the concept that COPD is a systemic disease and that exercise limitation is multifactorial, involving not only ventilatory limitation but also cardiovascular, musculoskeletal, and peripheral factors. Therefore, a comprehensive assessment and management approach addressing these comorbidities is essential to optimize functional outcomes in COPD patients.

Regarding reasons for CPET termination, the most common cause was leg pain in 27 (54%) patients, followed by breathlessness (18%), desaturation (18%), chest discomfort/palpitations (4%), blood pressure rise (4%), and ECG changes (2%). Leg pain was most frequent in patients with lower BODE scores—84.6% with BODE 0, 70% with BODE 1, and progressively less with higher BODE scores. Chi-square analysis showed a significant association between BODE score and reason for test termination ($p<0.05$), indicating that leg pain predominated in patients with lower BODE scores. A similar pattern was seen with GOLD grouping; leg pain was most common among GOLD Group A patients. Other causes of test termination showed no significant association with BODE score or GOLD group.

These findings are consistent with the study by Mahsa Miramadi et al,[13] who found leg pain to be the most common reason for CPET termination, particularly among patients with higher FEV_1%, indicating less advanced disease. Similarly, Ong KC et al,[14] reported that in 33 stable COPD patients, the main limiting factors were ventilatory limitation and desaturation, while limb muscle dysfunction and physical deconditioning contributed in those with submaximal effort. This suggests that leg fatigue predominates as a limiting factor in early COPD, while advanced stages are more affected by ventilatory and gas exchange abnormalities and other cardio respiratory factors. Identifying patients who stop exercise primarily due to leg fatigue is important, as they may derive the most benefit from early pulmonary rehabilitation.

This study has certain limitations. The sample size was relatively small (n=50) and conducted at a single center, which may limit generalizability. Only stable COPD patients were included, so findings may not apply to those with acute exacerbations or hemodynamic instability. The cross-sectional design precludes assessment of longitudinal changes in BODE index or CPET parameters over time. Muscle strength, nutritional status, and comorbid cardiovascular conditions were not comprehensively evaluated, which could have clarified their contribution to exercise limitation. Future multicentric studies with larger cohorts and longitudinal follow-up are warranted to confirm these findings and explore their prognostic implications.

CONCLUSION

In conclusion, this study demonstrated that among patients with stable COPD, the majority had low BODE scores and belonged to GOLD group A, reflecting milder disease status, yet they exhibited considerable functional limitations on CPET in terms of VO2max, %AT and METS. While VO_2max and AT atVO_2max showed no significant correlation with either BODE index or GOLD grouping, METS demonstrated a significant negative correlation with both, suggesting its potential as a sensitive indicator of functional impairment. The predominance of leg pain as the reason for exercise termination, especially in patients with lower BODE scores and GOLD group A, highlighted the role of peripheral muscle dysfunction early in the disease. These findings emphasize that COPD is a systemic condition where exercise limitation is multifactorial, arising due to cardiovascular (as evidenced by low VO2max and AT at VO2max) and musculoskeletal in addition to respiratory causes, underlining the importance of comprehensive management strategies, including early rehabilitation, to address peripheral muscle deconditioning alongside pulmonary dysfunction.

REFERENCES

1. Global Initiative for Chronic Obstructive Lung Disease [homepage on the Internet] Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. Bethesda: GOLD; 2025. http://www.goldcopd.org
2. World Health Report. Geneva: World Health Organization. Available from URL: https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death

3. Lopez AD, Shibuya K, Rao C, *et al.* Chronic obstructive pulmonary disease: current burden and future projections. EurRespir J 2006;27:397-412
4. Celli BR, Cote CG, Marin JM, Casanova C, Montes de Oca M, Mendez RA, Pinto Plata V, Cabral HJ. The Body mass index, airflow obstruction ,dyspnea, and exercise capacity in chronic obstructive pulmonary disease. N Engl J Med. 2004 Mar; 350(10):1005-12
5. Cote CG, Celli BR. BODE index: a new tool to stage and monitor progression of chronic obstructive pulmonary disease. PneumonolAlergol Pol. 2009;77(3):305-13
6. Ong KC, Ong YY. Cardiopulmonary exercise testing in patients with chronic obstructive pulmonary disease. Ann Acad Med Singapore 2000;29:648-52
7. Ortega F, Montemayor T, Sánchez A, Cabello F, Castollo J. A Role of cardiopulmonary exercise testing and the criteria used to determine disability in patients with severe chronic obstructive pulmonary disease. Am J RespirCrit Care Med 1994;150:747-51
8. S.K. Jindal1, A.N. Aggarwal *et al.* A Multicentric Study on Epidemiology of Chronic Obstructive Pulmonary Disease and its Relationship with Tobacco Smoking and Environmental Tobacco Smoke Exposure. The Indian Journal of Chest Diseases & Allied Sciences. 2006; 48: 24.
9. Jindal SK, Aggarwal AN, Gupta D, Agarwal R, Kumar R, Kaur T, *et al.* Indian study on epidemiology of asthma, respiratory symptoms and chronic bronchitis in adults (INSEARCH) Int J Tuberc Lung Dis. 2012;16:1270–7
10. Jindal SK *et al.* A review of population studies from India to estimate national burden of chronic obstructive pulmonary disease and its association with smoking.Indian J Chest Dis Allied Sci. 2001 Jul-Sep; 43 (3):139-47
11. S Chaurasia, T Dhamgaye. To study correlation of cardiopulmonary exercise testing parameters with BODE index and severity of COPD. European respiratory Journal 2014 44:213
12. A.A Ganju , A.B Fuladi *et al.* Cardiopulmonary Exercise Testing in Evaluation of Patients of Chronic Obstructive Pulmonary Disease. The Indian Journal of Chest Diseases & Allied Sciences. 2011; 53:87-91.
13. M Miramadi *et al.* Correlation of cardiopulmonary exercise testing parameters with quality of life in stable COPD patients. J Thorac Dis.2016 Aug;8 (8) :2138-2145
14. Ong KC, Ong YY. Cardiopulmonary exercise testing in patients with chronic obstructive pulmonary disease.AnnAcad Med Singapore. 2000 Sep;29(5):648-52