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ORIGINAL ARTICLE

Utility of the Fifteen Steps Climbing Exercise Oximetry Test in Assessing Disease Severity in Stable COPD Patients- A Cross Sectional Study

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Abstract

Background: *Forced Expiratory Volume in the first second (FEV_1) from spirometry is essential in diagnosing and managing COPD. Early detection of severe COPD in primary care is vital for timely referral and treatment. Spirometry is often underutilized in rural areas due to limited resources. The Fifteen Steps Climbing Exercise Oximetry Test (15SCT) offers an alternative for assessing COPD severity.*

Objective: *To evaluate the efficacy of 15SCT in determining disease severity in stable COPD patients.*

Methods: *This cross-sectional study was conducted at the National Institute of Diseases of the Chest and Hospital (NIDCH) from June 2022 to August 2023, involving 116 stable COPD patients. Spirometry confirmed COPD diagnosis and severity grading. Pulse, respiratory rate, and oxygen saturation (SpO_2) were measured pre- and post-15SCT. Data were analyzed using SPSS v.23, employing Paired t-test, Unpaired t-test, and ROC curve analysis.*

Results: *Patients (mean age 61.3±8.1 years; M:F = 22.2:1) showed moderate (50.0%), severe (43.1%), very severe (5.2%) and mild (1.7%) COPD. Most patients (52.6%) took 61-90 seconds for 15SCT. Post-15SCT SpO_2 significantly decreased from baseline (92.9±2.3% vs. 96.3±1.3%; $p<0.05$). Patients with $FEV_1<50\%$ had higher SpO_2 reduction (4.37±1.12%) than those with $FEV_1 \geq 50\%$ (2.51±0.96%). ROC analysis identified a $\geq 3.5\%$ SpO_2 drop as indicative of severe airflow limitation with good sensitivity (80.4%), specificity (90.0%) positive predictive value (88.2%), and negative predictive value (83.1%).*

Conclusion: *Significant exercise-induced desaturation correlated with COPD severity, supporting 15SCT as a useful tool for predicting severe airflow limitation in stable COPD patients.*

Keywords: *COPD, 15SCT, oximetry, step test.*

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Introduction

Chronic Obstructive Pulmonary Disease (COPD) is one of the leading causes of death globally, characterized by progressive airflow limitation due to chronic inflammation of the airways and lung tissue[1]. Prolonged exposure to noxious particles or gases, such as cigarette smoke or biomass fuel, leads to structural lung changes[2, 3]. In Bangladesh, it is a neglected public health issue, as about 12.5% of adults suffer from COPD, predominantly elderly, resulting in significant morbidity and mortality[4].

With genetic factors being important determinants, COPD encompasses chronic bronchitis, small airway disease, and emphysema, with significant systemic effects[5]. Destruction of alveoli, terminal bronchioles, and capillary vessels, along with airway fibrosis and secretion, compromises the respiratory membrane and reduces gas transfer capacity, leading to decreased inspiratory capacity and breathlessness on exertion with reduced exercise capacity[6]. Hypoxemia in COPD results from ventilation-perfusion (V/Q) mismatch, worsening with disease progression[7]. The systemic inflammation in COPD raises pro-inflammatory cytokines, causing a range of different extra-pulmonary manifestations like- excessive weight loss, skeletal muscle dysfunction, diminished muscle strength, lower limb muscle atrophy, hindering activities like- walking, stair climbing etc.[8, 9, 10, 11].

COPD severity is typically graded by Forced Expiratory Volume in the first second (FEV_1) via spirometry, which is a reproducible, non-invasive and gives an objective measurement of airflow limitation, widely available in most resource abundant countries[1] (GOLD, 2022). However, in resource-limited settings, exercise tests, which capture the integrated and multisystem effects of COPD, are crucial in assessing disease severity and facilitating timely referral to higher centers[12]. Pulse oximetry, an inexpensive and non-invasive method, measures SpO_2 before and after exercise, may indicate COPD disease severity in terms of significant decrease in SpO_2 which correlates with severe airflow limitation and a positive smoking history[13].

Studies conducted by several authors have shown a strong association between severe airflow limitation (FEV_1<45%) and exercise-induced oxygen desaturation in the 6-minute walk test (6MWT) and 2-minute walk test (2MWT)[14, 15, 16]. Step tests, first studied in as early as 1985, are efficient in eliciting higher metabolic and ventilatory responses than 6MWT, as they recruit less frequently used muscle groups[17]. Various step tests have been used to evaluate pulmonary disease severity, though many lack consistent validation against gold standard cycle ergometry Cardio-Pulmonary Exercise Test (CPET)[18].

The Fifteen Steps Climbing Oximetry Test (15SCT) is a simple step test conducted on a standard staircase. Patients climb up and down as rapidly as they can without pacing. Studies have compared exercise-induced oxygen desaturation in 15SCT with 6MWT, 2MWT, and CPET in COPD patients[16, 19]. The 15SCT is easy to perform, requiring less time, patient familiarization, and space, making it feasible in various settings.

This study aims to evaluate the 15SCT's clinical utility in assessing disease severity in stable COPD patients by measuring post-exercise oxygen desaturation. We also seek to establish a statistical cut-off for severe to very severe COPD.

Materials and methods

This cross- sectional observational study was carried out in the Department of Respiratory Medicine of National Institute of Diseases of the Chest and Hospital (NIDCH), Mohakhali, Dhaka between June 2022 and August 2023.

Inclusion criteria were:

1. Patients coming to NIDCH who are diagnosed as a case of COPD on the basis of GOLD guideline.
2. Patients with stable COPD for a minimum duration of 4 weeks.
3. Patient's age >40 years.
4. Patients willing to participate in this study.

Exclusion criteria were:

1. COPD patients on acute exacerbation
2. COPD patients with chronic respiratory failure or on long term oxygen therapy
3. Presence of other lung disease like Asthma, Diffuse Parenchymal Lung Disease (DPLD) or bronchiectasis etc.

4. A recent acute coronary syndrome (unstable angina or myocardial infarction) and acute heart failure
5. Patients with active malignancy, orthopedic or neurological diseases with walking difficulties.

A total of 116 patients with stable COPD, attending in the Outpatient Department of NIDCH were selected through convenient sampling method. Informed written consent was taken from all the patients in presence of witness, after proper explanation about the study protocol. Relevant clinical history was taken and physical examination was performed. All individuals were subjected to spirometry including the reversibility test. The best record from three attempts was selected and recorded to obtain the forced vital capacity (FVC), FEV_1 and FEV_1/FVC ratio. All the patients were categorized according to GOLD grading of severity into mild, moderate, severe and very severe on the basis of FEV_1. Baseline data (FEV_1, FEV_1/FVC, resting pulse, respiratory rate and SpO_2) was collected and then all the patients were subjected to 15 Steps Climbing Exercise Oximetry Test(15SCT) on the same day, about 1 hour later, on a regular staircase having steps of standard height and a strong support railing without fixed pacing. Then pertinent post-exercise data (pulse, respiratory rate, SpO_2 and exercise time) was collected.

Results

Out of the 116 patients, three fourth (75.0%) patients belonged to age group 56-70 years. The mean age was 60.4±7.2 years with a age from 42 to 75 years. Male patients significantly outnumbered females 111(95.7%) and most of the patients were service holders 50(43.1%). Mean BMI of the patients was found 21.2±3.5 kg/m^2. More than half 61(52.6%) patients were current smokers, 50(43.1%) were ex-smokers and 5(4.3%) were non-smokers, while 5(4.3%) patients had exposure to biomass fuel. 22(19.0%) patients had HTN, 18(15.5%) patients had DM, 8(1.7%) had IHD, 2(1.7%) had CKD and 1(0.9%) had CLD. Three (2.6%) patients had multiple co-morbidities. Most of the patients had mMRC grade 1 (32.8%) or grade 2 (31.0%) dyspnea.

In post bronchodilator spirometry, the mean FEV_1 was 51.3±13.5% with a range of 22.0-88.0%. Majority 58(50.0%) patients had moderate COPD, 50(43.1%) had severe, 6(5.2%) had very severe and 2(1.7%) had mild COPD. Mean SpO_2 was significantly reduced after 15SCT than baseline (92.9±2.3 vs 96.3±1.3%) with mean difference 3.4%, 95% CI (3.1 to 3.6%). Mean pulse was 91.2±5.7 beats/min and respiratory rate was 18.3±1.6 breath/min) after 15SCT. The mean exercise time was 71.5±17.0 seconds, where more than half (52.6%) patients took between 61-90 seconds to complete the exercise. Mean 15SCT time was significantly higher in COPD patients with FEV_1<50% (81.5±15.8 seconds) than in patients with FEV_1 ≥50% (62.2±12.1 seconds). In a similar fashion, mean oxygen saturation difference (between before and after 15SCT) was significantly higher in COPD patients

Table- I

Demographic Distribution of the study population (n=116)

Demographic characteristics	Number of patients	Percentage
Age (years)		
40-55	28	24.1
56-70	87	75
>70	1	0.9
Mean±SD	60.4	±7.2
Range (min-max)	42.0	-75.0
Male	111	95.7
Female	5	4.3
Occupational status		
Service holder	50	43.1
Cultivator	28	24.1
Day laborer	15	12.9
Businessman	11	9.5
Retired	7	6.0
House wife	5	4.3
BMI (kg/m^2)		
Underweight (<18.5)	36	31.0
Normal (18.5-22.9)	42	36.2
Overweight (23.0-24.9)	20	17.2
Obese (≥25.0)	18	15.5
Mean±SD	21.2	±3.5
Range (min-max)	15.2 - 29.7	

Table- II

Distribution of patients by their smoking status and history of exposure to biomass fuel (n=116)

Exposure to noxious agents	Number of Patients	Percentage
Smoking Status		
Current Smokers	61	52.6
Ex-Smokers	50	43.1
Non-Smokers	5	4.3
Exposure to biomass fuel		
Yes	5	4.3
No	111	95.7

having FEV_1<50% (4.37±1.12%) than in patients having FEV_1 ≥50% (2.51±0.96%).

Receiver operating characteristic (ROC) curve was constructed by using oxygen saturation differences

Table- III

Distribution of the study population according to co-morbidities (n=116)

Co-morbidities	Number of patients	Percentage
HTN	22	19.0
DM	18	15.5
IHD	8	6.9
CKD	2	1.7
CLD	1	0.9

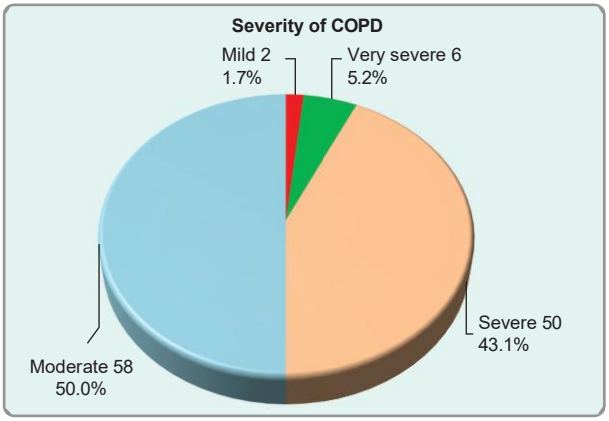

Figure 1: *Pie chart showing severity of airflow obstruction COPD according to post bronchodilator FEV_1 of the study population (n=116)*

Table-IV

SpO_2, pulse and RR at the beginning and after Fifteen Steps Climbing Oximetry Test (15SCT) (n=116)

	Baseline Mean±SD	After 15SCT Mean±SD	Mean difference (95% CI)	*P* value
SpO_2 (%)	96.3±1.3	92.9±2.3	3.4 (3.1 to 3.6)	0.001[s]
Pulse (beats/min)	85.6±6.2	91.2±5.7	5.6 (6.3 to 5.0)	0.001[s]
Respiratory rate (breaths/min)	16.3±0.9	18.3±1.6	2.0 (2.2 to 1.7)	0.001[s]

P value reached from paired t-test, s= significant

Table-V

Association between severity of airflow limitation of COPD and 15SCT time (n=116)

	Severity of COPD		F value	*P* value
	FEV_1 ≥50% (Mild +Moderate) (n=60) Mean±SD	FEV_1<50% (Severe+ Very severe) (n=56) Mean±SD		
15SCT time (seconds)	62.2±12.1	81.5±15.8	3.846	0.001[s]
Range (min-max)	30.0-90.0	50.0-130.0		

P value reached from unpaired t-test, s= significant

Table- VI

Association between severity of airflow limitation of COPD and oxygen saturation difference between before and after 15SCT (n=116)

	Severity of COPD		F value	*P* value
	FEV_1 ≥50% (Mild +Moderate) (n=60) Mean±SD	FEV_1<50% (Severe+ Very severe) (n=56) Mean±SD		
Oxygen saturation difference (%)	2.51±0.96	4.37±1.12	1.271	0.001[s]
Range (min-max)	0.0-6.0	2.0-8.0		

P value reached from unpaired t-test, s= significant

Table- VII

Valuation of oxygen saturation difference (ÄSpO₂) ≥3.5% against severe airflow limitation (FEV₁<50%) in stable COPD (n=116)

Oxygen Saturation difference ≥3.5%	Severe COPD according to GOLD 2022 grading	
	Positive (Severe+ Very severe) FEV₁<50% (n=56)	Negative (Mild +Moderate) (FEV₁ ≥50%) (n=60)
Positive (n=51)	45 (True positive)	6 (False positive)
Negative (n=65)	11 (False negative)	54 (True negative)

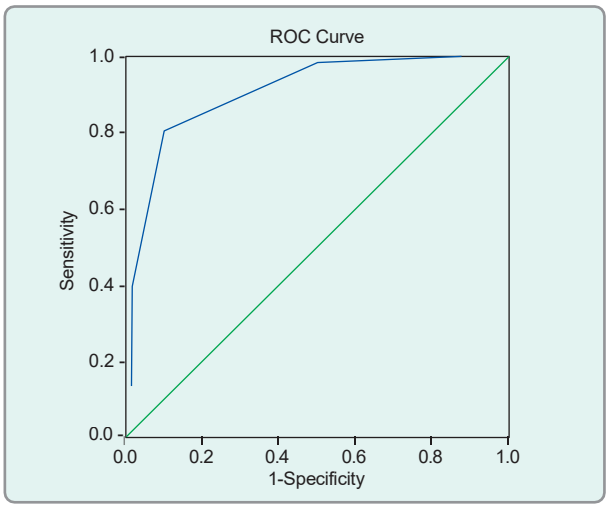

Figure- 2: *Receiver operating characteristic (ROC) curves of oxygen saturation (SpO_2) differences between baseline and after 15 steps climbing exercise oximetry test (n=116) gave a cut off value of ΔSpO_2 ≥3.5 percent with an area under curve 0.905.*

Table-VIII

Sensitivity, specificity, accuracy, positive and negative predictive values of the oxygen saturation difference (ΔSpO_2) ≥3.5%evaluation for prediction of severe airflow limitation (FEV_1 <50%) in stable COPD

Validity test	Percentage
Sensitivity	80.4
Specificity	90.0
Accuracy	85.3
Positive predictive value	88.2
Negative predictive value	83.1

(between before and after 15SCT), which gave a cut off value of ΔSpO_2 ≥3.5 percent, with 80.4% sensitivity and 90.0% specificity on validation against FEV_1 <50% (severe and very severe grades of stable COPD).

Discussion:

This cross-sectional study aimed to evaluate the usefulness of the 15 Steps Climbing Test (15SCT) in assessing disease severity in patients with stable COPD, based on FEV_1 measurements. Conducted with 116 patients at NIDCH, the study provides valuable insights.

Most participants (75%) were aged 56-70, with a mean age of 60.4±7.2 years, reflecting the increased risk of COPD with advancing age. This finding aligns with previous studies by Ganju et al. (2011), Rusanov et al. (2008), and Starobin et al. (2006)[20, 21, 22]. The predominance of male patients (95.7%) underscores the higher prevalence of COPD in men, likely due to higher smoking rates, as 52.6% were current smokers and 43.1% were ex-smokers. These results are consistent with the findings of Islam et al. (2013) and other studies[23]. This study shows that 5(4.3%) patients had exposure to biomass fuel.

The mean BMI of 21.2±3.5 kg/m^2 indicates no particular BMI group being more prone to COPD, similar to findings by Gloeckl et al. (2016) and Ganju et al. (2011)[20, 24]. Comorbidities were common, with 19% of patients having hypertension and 15.5% having diabetes, reflecting the multi-system impact of COPD. Three (2.6%) patients had multiple co-morbidities.

Dyspnea grading showed that most patients had mMRC grade 1 (32.8%) or grade 2 (31.0%) dyspnea,

with no patients at grade 4. Post-bronchodilator spirometry revealed a mean FEV_1 of 51.3±13.5% of predicted value, with most patients having moderate (50%) or severe (43.1%) COPD. These findings are consistent with Rusanov et al. (2008) and Ganju et al. (2011)[20, 21]. An inference can be drawn that, at outdoor of tertiary care hospitals like NIDCH, mild cases are relatively less encountered, while very severe cases are too ill and attend the emergency department.

The 15SCT exercise time was higher in patients with FEV_1<50%, indicating greater disease severity. This is supported by Negm et al. (2012) and Starobin et al. (2006), who observed increased exercise time with higher COPD severity[19, 22]. The study also found a significant reduction in mean SpO_2 after the 15SCT, with a greater decrease in patients with FEV_1<50%. Mean SpO_2 was significantly reduced after 15SCT than baseline (92.9±2.3 vs 96.3±1.3%) with mean difference 3.4%, with 95% CI (3.1 to 3.6%). Mean oxygen saturation difference was significantly higher in COPD patients having FEV_1<50% (4.37±1.12%) than in patients having FEV_1 ≥50% (2.51±0.96%). These findings are in alignment with those studies done by Starobin et al. (2006) and Negm et al. (2012)[19, 22].

Using ROC curves, the study established a cut-off value of ΔSpO_2 ≥3.5% for predicting severe COPD, with 80.4% sensitivity, 90.0% specificity and 85.3% accuracy. This finding offers a valuable clinical tool for assessing disease severity in resource-limited settings.

Overall, the study demonstrates the efficacy of the 15SCT in evaluating COPD severity, providing a practical, low-cost alternative to spirometry in outpatient settings. This study also stablishes a post exercise cut off value for SpO_2 difference of e"3.5 percent with a good sensitivity and specificity for prediction of severe airflow limitation in case of stable COPD.

Conclusion:

This study demonstrated significant differences in oxygen saturation between mild to moderate and severe to very severe COPD patients before and after the 15 Steps Climbing Oximetry Test (15SCT). Using receiver operating characteristic curves, a cut-off value of ΔSpO_2 ≥3.5% was established, showing good sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for predicting severe airflow limitation (FEV_1<50%) in stable COPD patients. Therefore, the 15SCT is a useful, quick, simple, inexpensive, and convenient test for detecting severe airflow limitation in stable COPD patients. Farther study with larger sample size, including larger no. of mild cases, undergoing continuous oximetry during exercise is recommended.

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