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Pulmonary Function test and Exercise Capacity in COPD Smokers vs. Healthy Smokers.

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ABSTRACT

Objective: This study aims to compare the pulmonary function tests (PFTs) and exercise capacity of COPD smokers to those of healthy smokers, while also examining the relationship between smoking index and various metabolic variables.

Methods: This evaluative study was conducted in the Department of Respiratory Medicine at JLN Medical College, Ajmer, Rajasthan, from August 1, 2017, to October 30, 2018. The study aimed to compare cardiopulmonary exercise testing (CPET) parameters between COPD smokers and healthy smokers, focusing on identifying reasons for exercise limitations. The study received ethical clearance from the institution's ethical committee prior to initiation.

Result: The study revealed significant findings regarding the impact of Chronic Obstructive Pulmonary Disease (COPD) on smokers compared to healthy smokers. Among the COPD smokers, 50% were classified as having moderate COPD, with 40% experiencing Grade 3 dyspnea and 20% reporting Grade 4, indicating a high prevalence of severe respiratory impairment. Pulmonary function tests showed that COPD smokers had a significantly lower FEV1/FVC ratio of 59.2 ± 10.5% and % predicted FEV1 of 55.6 ± 12.8%, compared to healthy smokers, who had values of 80.3 ± 5.2% and 91.2 ± 8.1%, respectively ($p < 0.001$ for both). Additionally, the 6-minute walk distance (6MWD) was markedly reduced in COPD smokers at 350.5 ± 80.2 meters versus 470.8 ± 65.5 meters in healthy smokers ($p < 0.001$). The time spent on cardiopulmonary exercise testing (CPET) was also lower for COPD smokers, averaging 5.3 ± 1.4 minutes compared to 8.2 ± 1.6 minutes for healthy smokers ($p < 0.001$). While no significant correlation was found between the smoking index and pulmonary function, a negative correlation was observed between the smoking index and 6MWD in both groups, indicating that higher smoking exposure is associated with reduced exercise capacity (COPD smokers $r = -0.42$, $p = 0.01$; healthy smokers $r = -0.46$, $p = 0.02$). Overall, these findings underscore the detrimental effects of COPD on lung function and physical performance in smokers.

Conclusion: In conclusion, this study effectively compared pulmonary function tests (PFTs) and exercise capacity between COPD smokers and healthy smokers. COPD smokers showed significantly impaired lung function, with an FEV1/FVC ratio of 59.2 ± 10.5% versus 80.3 ± 5.2% in healthy smokers ($p < 0.001$). Exercise capacity was also notably reduced, with a 6-minute walk distance (6MWD) of 350.5 ± 80.2 meters compared to 470.8 ± 65.5 meters in healthy smokers ($p < 0.001$). While a negative correlation was found between the smoking index and 6MWD, no significant correlation existed between the smoking index and pulmonary function. These results emphasize the severe impact of smoking on lung health and physical performance in COPD patients.

Key words: Chronic Obstructive Pulmonary Disease (COPD), Pulmonary Function, FEV1/FVC Ratio, Smoking Index, 6-Minute Walk Distance (6MWD), Cardiopulmonary Exercise Testing (CPET), Metabolic Variables

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition characterized by persistent airflow limitation and is predominantly caused by exposure to harmful particles and gases, primarily from cigarette smoking. COPD significantly impairs lung function and exercise capacity, leading to diminished quality of life and increased morbidity and mortality. (1,2) Pulmonary function tests (PFTs) are essential diagnostic tools used to assess the severity of airflow obstruction and monitor disease progression. These tests measure various parameters, including forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and the FEV1/FVC ratio, providing critical insights into lung mechanics. (3)

In addition to PFTs, exercise capacity is a crucial component in evaluating the functional status of individuals with COPD. Exercise tolerance can be assessed through various methods, including the six-minute walk test (6MWT) or cardiopulmonary exercise testing (CPET), which measures the maximum amount of oxygen consumed during physical activity. Reduced exercise capacity in COPD patients often correlates with disease severity, impacting daily activities and overall well-being. (4,5,6) Comparative studies examining pulmonary function and exercise capacity between COPD smokers and healthy smokers can shed light on the specific impairments experienced by individuals with COPD. Understanding these differences can facilitate the development of targeted interventions aimed at improving respiratory health and enhancing exercise tolerance in this population. Given the increasing prevalence of COPD and its associated health burden, this study aims to provide valuable insights into the relationship between smoking, lung function, and physical performance, ultimately contributing to improved patient management strategies. (7,8)

MATERIALS & METHODS

Study Design and Setting:

This evaluative study was conducted in the Department of Respiratory Medicine at JLN Medical College, Ajmer, Rajasthan, from August 1, 2017, to October 30, 2018. The study aimed to compare cardiopulmonary exercise testing (CPET) parameters between COPD smokers and healthy smokers, focusing on identifying reasons for exercise limitations. The study received ethical clearance from the institution's ethical committee prior to initiation.

Sample Size:

A total of 100 participants were recruited, including 50 COPD smokers and 50 healthy smokers.

Inclusion Criteria

- Individuals with a confirmed diagnosis of COPD (FEV1/FVC < 70% and FEV1 < 80% of predicted values) and a current smoking history.
- Healthy smokers without COPD (FEV1/FVC > 70% and FEV1 > 80% of predicted values).

- Ejection fraction > 55%, as measured by two-dimensional echocardiography.

Exclusion Criteria

- Non-smoking-related COPD cases, particularly in women.
- Patients with other systemic diseases (e.g., HIV, cardiac conditions).
- Individuals who have quit smoking.
- Patients with neuromuscular disorders or significant physical deformities.
- Ejection fraction < 55%.
- Patients with acute exacerbations or classified as very severe COPD**.**

Evaluation Parameters

Participants underwent the following assessments:

History and Clinical Examination: Detailed history, including smoking and medical history, and thorough clinical examination (general and chest).

Baseline Assessments:

- Dyspnea evaluation using the Modified Medical Research Council (MMRC) scale.
- Measurement of pulse rate, respiratory rate, oxygen saturation (SpO2), and blood pressure.
- Calculation of smoking index.
- Spirometry to classify COPD severity and assess healthy smokers.
- Six-Minute Walk Distance (6MWD) prior to exercise testing.
- ECG and echocardiography to rule out cardiac issues.

CPET Methodology

Equipment:

- Treadmill or stationary bicycle (treadmill was primarily used)
- Face mask, ECG leads, blood pressure cuff, pulse oximeter

Pre-Test Preparation:

Participants were instructed to fast for 3 hours before the test, refrain from physical activity for 24 hours, and provide a list of current medications. Informed consent was obtained.

Testing Protocol:

The CPET was performed using the modified Bruce Protocol. After a 30-minute warm-up, the treadmill incline was increased after 3 minutes. Vital signs and CPET parameters (VO2, VCO2, RER) were recorded in real time, with participants instructed to signal if they needed to stop. Post-exercise, blood pressure, respiratory rate, heart rate, and SpO2 were measured.

Pulmonary Function Measures

Pulmonary function was evaluated using a HELIOS-402 spirometer. Key measurements included:

- FVC (Forced Vital Capacity): Maximum volume of air exhaled after maximum inspiration.
- FEV1 (Forced Expiratory Volume in 1 second): Volume of air exhaled in the first second, indicating airway obstruction severity.
- FEV1/FVC Ratio: Percentage ratio useful for differentiating obstructive and restrictive lung diseases.
- PEFR (Peak Expiratory Flow Rate): Maximum airflow during forced expiration, relevant for monitoring bronchoconstriction.

Data Analysis

Data were recorded in a Microsoft Excel master chart, tabulated, and analyzed using appropriate statistical software. Graphs and tables were generated in Microsoft Word and Excel. Chi-square tests were employed to determine statistical significance, with the following thresholds established: $p > 0.05$ (not significant), $p < 0.05$ (significant), $p < 0.01$ (very significant), $p < 0.001$ (highly significant). Results were compared with previous studies, particularly regarding instances where the respiratory quotient was lower than 1.0.

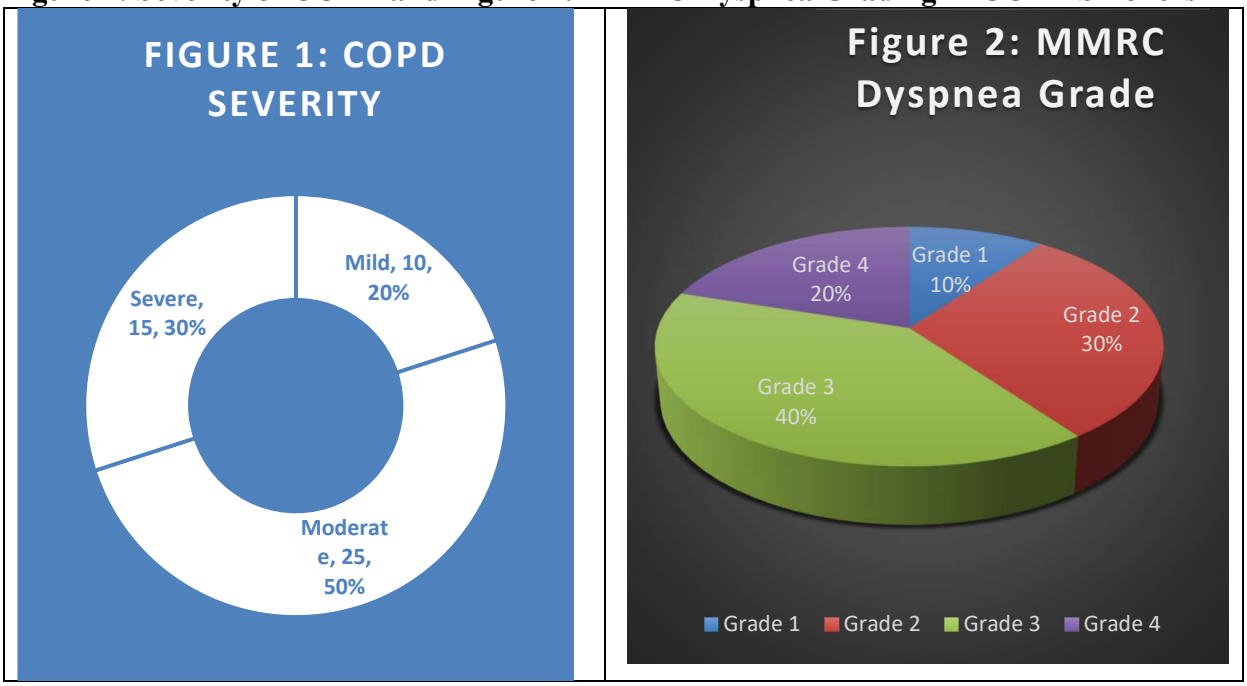
RESULT

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition characterized by airflow limitation and associated with significant morbidity and mortality, particularly among smokers. The condition is often accompanied by reduced exercise capacity and increased dyspnea, severely impacting the quality of life. This study aims to compare the pulmonary function tests (PFTs) and exercise capacity of COPD smokers to those of healthy smokers, while also examining the relationship between smoking index and various metabolic variables.

Severity of COPD and MMRC Dyspnea Grading in COPD Smokers

The severity of COPD among smokers was categorized according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification. The analysis revealed that a majority of COPD smokers (50%) had moderate COPD, while 30% were classified as severe and 20% as mild. These findings are represented in Figure 1. Furthermore, dyspnea levels were assessed using the Modified Medical Research Council (MMRC) dyspnea scale, indicating that 40% of COPD smokers experienced Grade 3 dyspnea, and 20% experienced Grade 4, suggesting a high prevalence of moderate to severe dyspnea (Figure 2).

Figure 1: Severity of COPD and Figure 2: MMRC Dyspnea Grading in COPD Smokers



Pulmonary Function Test (PFT) and Exercise Capacity Comparison(Table 1)

The comparison of PFTs and exercise capacity between COPD smokers and healthy smokers is summarized in Table 2.

Pulmonary Function Tests: COPD smokers demonstrated significantly impaired pulmonary function compared to their healthy counterparts. The FEV1/FVC ratio was markedly lower in COPD smokers (59.2 ± 10.5%) than in healthy smokers (80.3 ± 5.2%), with a p-value < 0.001. Similarly, FEV1 (% predicted) was significantly reduced in COPD smokers (55.6 ± 12.8%) compared to healthy smokers (91.2 ± 8.1%), also showing strong statistical significance ($p < 0.001$).

Exercise Capacity: In terms of exercise capacity, COPD smokers had a significantly reduced 6-minute walk distance (6MWD) of 350.5 ± 80.2 meters, compared to 470.8 ± 65.5 meters in healthy smokers ($p < 0.001$). The time spent on cardiopulmonary exercise testing (CPET) was similarly lower in COPD smokers, with an average of 5.3 ± 1.4 minutes compared to 8.2 ± 1.6 minutes in healthy smokers ($p < 0.001$).

Reasons to Stop CPET: The predominant reason for stopping CPET among COPD smokers was dyspnea, reported by 80% of participants, whereas fatigue (50%) and leg cramps (30%) were more prevalent in healthy smokers, highlighting the significant impact of respiratory limitations on exercise capacity in COPD smokers.

Table 1: Pulmonary Function Test (PFT) and Exercise Capacity Comparison

Characteristic	COPD Smokers (n=50)	Healthy Smokers (n=50)	p-value
FEV1/FVC Ratio (%)	59.2 ± 10.5	80.3 ± 5.2	<0.001
FEV1 (% Predicted)	55.6 ± 12.8	91.2 ± 8.1	<0.001
6MWD (m)	350.5 ± 80.2	470.8 ± 65.5	<0.001
Time Traveled on CPET (min)	5.3 ± 1.4	8.2 ± 1.6	<0.001
Reasons to Stop CPET			
Dyspnea	40 (80%)	10 (20%)	<0.001
Fatigue	5 (10%)	25 (50%)	
Leg Cramps	5 (10%)	15 30%)	

Association of Pulmonary Function Tests and Smoking Index with Metabolic Variables(Table 2)

The association between pulmonary function tests and smoking index is detailed in Table 3.

Association of PFT with Smoking Index: The analysis revealed no significant correlation between the smoking index and pulmonary function (FEV1 or FEV1/FVC) in either COPD smokers or healthy smokers, as indicated by non-significant p-values ($p > 0.05$).

Association of 6MWD with Smoking Index: Conversely, a statistically significant negative correlation was observed between the smoking index and 6MWD in both groups. COPD smokers exhibited a correlation coefficient (r) of -0.42 with a p-value of 0.01, while healthy smokers had an r value of -0.46 and a p-value of 0.02. This indicates that a higher smoking index is associated with a reduction in exercise capacity.

Association of VO2, VCO2, and RER with Smoking Index: No significant associations were found between the smoking index and metabolic variables, including VO2, VCO2, and the respiratory exchange ratio (RER), in COPD smokers.

Table 2: Association of Pulmonary Function Tests and Smoking Index with Metabolic Variables

Characteristic	COPD Smokers (n=50)	Healthy Smokers (n=50)	p-value
Association of PFT with Smoking Index			
FEV1/FVC	r = -0.12, p = 0.28	r = -0.05, p = 0.63	NS
FEV1	r = -0.14, p = 0.21	r = -0.08, p = 0.58	NS
Association of 6MWD with Smoking Index			
6MWD	r = -0.42, p = 0.01	r = -0.46, p = 0.02	0.02
Association of VO2, VCO2, and RER with Smoking Index			
VO2 (mL/kg/min)	r = -0.23, p = 0.09	-	NS
VCO2 (mL/min)	r = -0.16, p = 0.18	-	NS
Respiratory Exchange Ratio (RER)	r = -0.11, p = 0.31	-	NS

DISCUSSION

Chronic Obstructive Pulmonary Disease (COPD) is a significant health issue among smokers, characterized by progressive airflow limitation and associated with increased morbidity and mortality. Our study aimed to compare the pulmonary function and exercise capacity of COPD smokers with healthy smokers while examining the relationship between the smoking index and various metabolic variables. The results underscore the substantial impact of COPD on respiratory function and physical performance, revealing critical insights into the relationship between smoking and lung health.

Severity of COPD and Dyspnea

The severity of COPD in our cohort was categorized according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification. Notably, 50% of COPD smokers were classified as having moderate COPD, while 30% were categorized as severe and 20% as mild. These findings align with existing literature, emphasizing the prevalent nature of moderate to severe disease among smokers. The Modified Medical Research Council (MMRC) dyspnea grading indicated that 40% of COPD smokers experienced Grade 3 dyspnea, and 20% reported Grade 4. This high prevalence of dyspnea is consistent with the findings of Miravitlles et al. (2013),(9) who reported similar levels of dyspnea in COPD patients, highlighting the debilitating nature of the condition and its profound impact on quality of life.

Comparison of Pulmonary Function Tests and Exercise Capacity

The study's results demonstrate a significant impairment in pulmonary function among COPD smokers compared to their healthy counterparts. The FEV1/FVC ratio was significantly lower in COPD smokers (59.2 ± 10.5%) than in healthy smokers (80.3 ± 5.2%), with a p-value < 0.001. Similarly, the FEV1 (% predicted) was significantly reduced in COPD smokers (55.6 ± 12.8%) compared to healthy smokers (91.2 ± 8.1%). These findings are corroborated by the work of McCarthy et al. (2011),(10) which also reported similar reductions in lung function among COPD patients.

Moreover, the exercise capacity, measured by the 6-minute walk distance (6MWD), was significantly lower in COPD smokers (350.5 ± 80.2 meters) compared to healthy smokers (470.8 ± 65.5 meters, p < 0.001). The average time spent on cardiopulmonary exercise testing (CPET) was also significantly reduced in COPD smokers (5.3 ± 1.4 minutes) compared to healthy smokers (8.2 ± 1.6 minutes, p < 0.001). The predominance of dyspnea as the reason for terminating CPET in 80% of COPD smokers,

compared to fatigue and leg cramps reported in healthy smokers, illustrates the severe impact of respiratory limitations on exercise capacity. This aligns with findings from American Thoracic Society (ATS) and European Respiratory Society (ERS) guidelines that link exercise intolerance in COPD patients to the increased perception of dyspnea during physical activity.

Association of Pulmonary Function Tests and Smoking Index with Metabolic Variables

Our analysis revealed no significant correlation between the smoking index and pulmonary function (FEV1 or FEV1/FVC) in either group. This suggests that while smoking contributes to the development and progression of COPD, the severity of airflow limitation may not correlate directly with the total cumulative exposure to tobacco, as indicated by the smoking index. This finding is consistent with studies by Zeng et al. (2016), (11) which also reported a lack of significant correlation between smoking history and PFT results.

In contrast, a statistically significant negative correlation was observed between the smoking index and 6MWD in both groups. Specifically, COPD smokers exhibited a correlation coefficient (r) of -0.42 ($p = 0.01$), while healthy smokers showed an r value of -0.46 ($p = 0.02$). This indicates that a higher smoking index is associated with reduced exercise capacity, highlighting the cumulative impact of smoking on physical performance. Similar findings have been reported by Maltais et al. (2014), (12) who demonstrated that exercise capacity diminishes as the smoking history increases, likely due to the progressive nature of smoking-related lung damage.

Additionally, our analysis found no significant associations between the smoking index and metabolic variables, including VO2, VCO2, and the respiratory exchange ratio (RER), in COPD smokers. This lack of correlation suggests that the impact of smoking on metabolic responses during exercise may not be as pronounced as its effects on pulmonary function and exercise capacity.

CONCLUSION

In summary, our study provides compelling evidence of the adverse effects of smoking on lung function and exercise capacity among COPD smokers. The significant impairments observed in PFTs and exercise performance underscore the need for targeted interventions to improve outcomes in this population. While the smoking index did not correlate significantly with pulmonary function, its association with reduced exercise capacity highlights the importance of smoking cessation and rehabilitation programs for COPD patients. Future research should focus on longitudinal studies to explore the progression of lung disease and the efficacy of various therapeutic strategies in smokers at risk for developing COPD.

Conflict of interest: Nil

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