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Significance of peak oxygen pulse in patients with chronic obstructive pulmonary disease

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Abstract

Background Patients with chronic obstructive pulmonary disease (COPD) are more likely to develop cardiovascular comorbidities, such as pulmonary hypertension or heart failure. COPD patients are frequently adversely affected by compromised cardiovascular function. Oxygen pulse (O2P) serves as a proxy for stroke volume. However, studies concerning O2P, health-related quality of life (HRQL), and exercise capacity in COPD patients are lacking. Our objective was to verify the association between O2P, exercise capacity, and severe COPD exacerbation.

Materials and methods Fifty COPD patients were evaluated using spirometry, echocardiography, and a cardiopulmonary exercise test (CPET) for this study. Hospitalizations and emergency department visits due to COPD, as well as cardiovascular co-morbidities, were tracked. Patients with normal peak O2P and those with impaired peak O2P were compared for these measures. Peak oxygen consumption (O2P) was correlated with cardiopulmonary exercise testing (CPET) and lung function by simple linear regression.

Results Higher exercise capacity (peak oxygen uptake and work rate) and fewer hospitalizations due to COPD were observed in patients with normal peak O2P. Forced expiratory volume in one second (FEV1) was found to have a statistically significant correlation with arterial oxygen pressure (O2P) in a linear regression model.

Conclusion Hospitalization due to COPD and exercise ability are both significantly affected by peak O2P. Peak O2P is strongly correlated with FEV1. The severity of COPD can be measured in part by the patient's peak O2P.

Keywords Cardiopulmonary exercise (CPET), Peak oxygen pulse, Chronic obstructive pulmonary disease (COPD)

Introduction

Cough, dyspnea, chest tightness, etc. are some of the respiratory symptoms associated with chronic obstructive pulmonary disease (COPD), a condition brought on by prolonged exposure to noxious particles or gases [1].

Heart function and chronic obstructive pulmonary disease (COPD) interact closely in terms of pathogenesis. Airway inflammation, lung emphysema, and pulmonary vascular alterations are the primary pathophysiological abnormalities in COPD [2].

Expiratory flow restriction, air trapping, and hyperinflation are all brought on by the obstruction and inflammation that characterize COPD. Impaired left heart diastolic filling is also linked to airway obstruction and hyperinflation [3]. Pulmonary hypertension is caused by a combination of factors, including the loss of pulmonary capillaries in emphysematous lungs, which raises vascular resistance, and pulmonary vascular remodeling, which includes intimal and smooth muscle hyperplasia [4].

The cardiopulmonary exercise test (CPET) is the gold standard for assessing exercise capacity and both ventilatory and circulatory functions in COPD patients. Oxygen pulse (O2P), derived from CPET, is a noninvasive proxy for stroke volume (SV). Although pulmonary artery catheterization is regarded as the gold standard for measuring cardiac output in intensive care, it is not commonly

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used in stable COPD patients due to its invasive nature and potential complications [5, 6].

Aim of the work

We set out to conduct a systematic review of the literature on the effects of peak O2P on exercise capacity and severe exacerbations of COPD in patients.

Patients

Our study included 50 COPD patients.

Inclusion criteria:

- Stable COPD patients.
- Capability to function independently on a cycle ergometer.

Exclusion criteria:

- Three-month history of unstable coronary syndrome.
- Neuromuscular diseases or major surgeries that will influence the exercise test.

Methods

All participants enrolled in the study have signed an informed consent prior to participation.

1. Thorough history taking, physical examination and eligibility screening: Data from the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guideline's ABCD assessment tool, including demographic and laboratory information as well as details on cardiovascular comorbidities [7, 8].
2. Pulmonary function tests [7, 8].
3. Cardiopulmonary Exercise Test (CPET):

Ergocard clinical exercise testing system was utilized for CPET according to ATS guidelines [9].

4. Echocardiogram:

All patients underwent standard echocardiogram using a Philips HD7 ultrasound system (Philips Healthcare, Amsterdam, the Netherlands) and a 1–3 MHz Philips S3-1 cardiac sector transducer (Philips Healthcare, Amsterdam, the Netherlands) to assess the presence of heart failure (systolic or diastolic) and stroke volume [10].

Statistical analysis

The computer was supplied data, which was then analyzed using IBM SPSS version 20.0 software. (Armonk, NY: IBM Corp. Numbers and percentages were used to depict categorical data. Two groups were compared using the Chi-square test. Alternately, Fisher Exact and Monte Carlo correction tests were utilized when over 20% of the cells had an expected count of less than 5. The Shapiro–Wilk test was used to examine continuous data for normality. Quantitative data for normally distributed variables were expressed as range (minimum and maximum), mean, standard deviation, and median. Two groups were compared using a Student t-test. In contrast, the Mann Whitney test was used to compare two groups with quantitative variables that were not normally distributed. At the 5% significance level, the derived results were deemed significant.

Results

Table 1 and Figs. 1 and 2 show the baseline characteristics of the studied population.

Our studied population were divided into two groups:

Group I: COPD patients with normal peak o2 pulse (16 patients).
Group II: COPD patients with low peak o2 pulse (34 patients).

There was no statistically significant difference between the two groups regarding age, median 59.50(53.0 – 62.0). All patients were males except one female patient only in group two cause of exposure history. The weights of the two groups differed significantly from one another, mean 86.50 ± 14.39 in group one versus70.21 ± 12.68 in group two with $p < 0.001$. Regarding BMI, a statistically significant distinction existed between the two categories with mean 30.53 ± 5.17 in group one and 25.22 ± 4.55 in group two with $p = 0.001$.

Regarding smoking history, In regards to smoking habits, there was no discernible difference between the groups ($p = 1.000$), there were 36patients active smokers while 14 patients only were ex- smokers (Table 1).

Regarding Comorbidities, hypertension, arrhythmia, and valvular disease were not substantially different between the two groups tested. Our study included 25 patients with congestive heart failure(CHF), 2 patients in group one and 23 in group two which made supported distinction by statistics between the two groups ($p < 0.001$). Regarding coronary artery disease(CAD), our study included 23 patients with CAD,2 patients in group one and 21in group two which was also statistically significant different ($p = 0.001$) (Table 2).

Table 1 Comparison between the two studied groups according to different parameters

	Total ($n=50$)	Group I ($n=16$)	Group II ($n=34$)	Test of Sig	*p*
Sex					
Male	49 (98%)	16 (100%)	33 (97%)	$\chi^2=0.480$	$^{FE}p=1.000$
Female	1 (2%)	0 (0%)	1 (3%)		
Age (/years)					
Mean ± SD	57.0 ± 9.10	54.63 ± 8.61	58.12 ± 9.24	t = 1.274	0.209
Median (Min. – Max.)	59.50(31.0 – 75.0)	54.0(43.0 – 75.0)	60.0(31.0 – 74.0)		
BH (cm)					
Mean ± SD	168.0 ± 6.32	168.4 ± 7.96	167.8 ± 5.52	t = 0.348	0.729
Median (Min. – Max.)	169.5(152.0–183.0)	170.5(152.0–183.0)	167.0(155.0–180.0)		
BW (kg)					
Mean ± SD	75.42 ± 15.18	86.50 ± 14.39	70.21 ± 12.68	$t=4.060^*$	$<0.001^*$
Median (Min. – Max.)	74.0(50.0 – 115.0)	85.0(60.0 – 115.0)	68.50(50.0 – 100.0)		
BMI (kg/m^2)					
Mean ± SD	26.92 ± 5.33	30.53 ± 5.17	25.22 ± 4.55	$t=3.902^*$	$<0.001^*$
Median (Min. – Max.)	25.85(16.5 – 38.95)	30.20(24.3 – 38.95)	24.65(16.5 – 38.29)		
Hemoglobin					
Mean ± SD	12.67 ± 1.27	12.78 ± 1.18	12.63 ± 1.32	t = 0.383	0.703
Median (Min. – Max.)	12.50(10.50–15.20)	12.65(11.0–15.10)	12.50(10.50–15.20)		
Gold					
I	7 (14%)	5 (31%)	2 (6%)	$\chi^2=9.906^*$	$^{MC}p=0.014^*$
II	11 (22%)	4 (25%)	7 (21%)		
III	22 (44%)	7 (44%)	15 (44%)		
IV	10 (20%)	0 (0%)	10 (29%)		
ABCD assessment					
A	2 (4%)	2 (13%)	0 (0%)	$\chi^2=19.845^*$	$^{MC}p<0.001^*$
B	12 (24%)	9 (56%)	3 (9%)		
C	18 (36%)	4 (25%)	14 (41%)		
D	18 (36%)	1 (6%)	17 (50%)		
Smoking					
Current smoker	36 (72%)	12 (75%)	24 (71%)	$\chi^2=0.105$	$^{FE}p=1.000$
Ex–smoker	14 (28%)	4 (25%)	10 (29%)		

SD **Standard deviation**, *t* **Student t-test,** χ^2 **Chi square test**, *FE* **Fisher Exact,** *MC* **Monte Carlo,** *p* p value for comparing between the two studied groups

* Statistically significant at $p \leq 0.05$

Group I: Normal Peak O_2 pulse

Group II: Low Peak O_2 pulse

Regarding GOLD classification, our study included 5 patient GOLD I in group one while only 2 patients in group 2. There were 4 patients classified as GOLD II in group one while 7 in group two. Seven patients were classified as GOLD III in group one while 15 in group two. In group one there were no patients classified as GOLD IV while we had 10 patients in group two. Overall In terms of GOLD categorization, there was a significant difference in statistics between the groups. ($p=0.014$) (Table 1, Fig. 3).

Regarding ABCD classification, our study included 2 patients class A, 12 class B, 18 class C and 18 class D with more patients of class C and D in group two patients which make noticeable dissimilarity between the two groupings. ($p<0.001$) (Table 1, Fig. 4).

Regarding Echo parameters Statistical tests revealed a substantial divergence regarding the stroke volume with median 36.50(35.0 – 39.0), 60.0(38.0 – 63.0) in group 1 and 2 respectively. ($p=0.004$) (Table 2, Fig. 5).

Regarding exercise capacity, Peak oxygen consumption (VO2) (l/min) and Peak VO2 (% predicted) values varied significantly amongst the groups since the median of peak vo2 (l/min) in group one was 1.64(1.4–1.9) versus 1.0(0.83–1.1) in group two with $p<0.001$.

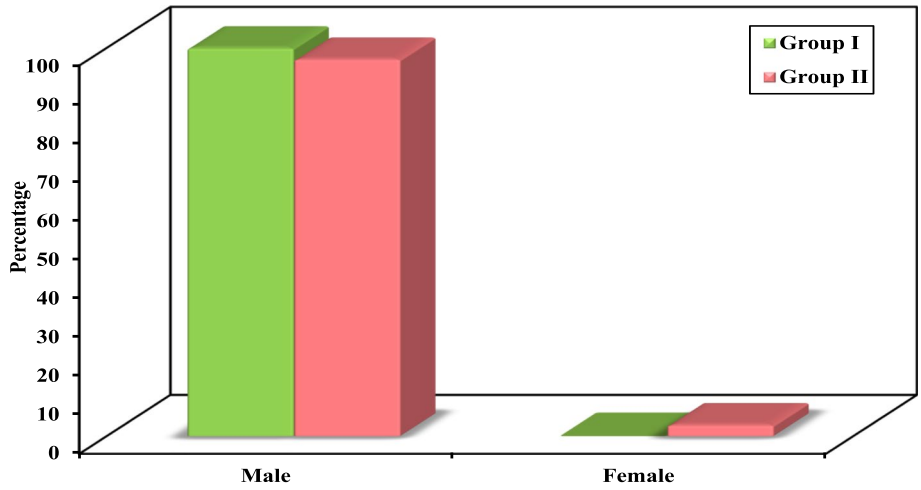

Fig. 1 Comparison between the two studied groups according to sex

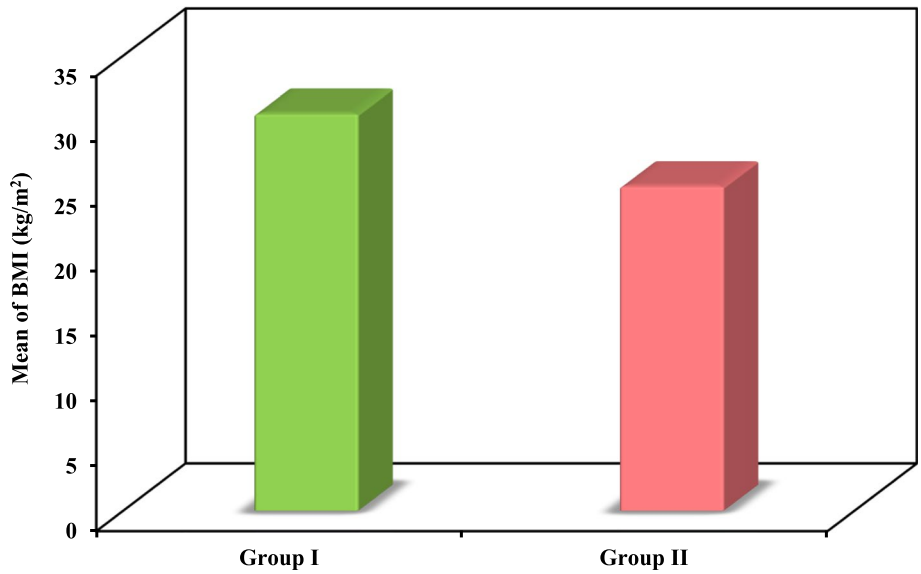

Fig. 2 Comparison between the two studied groups according to BMI (kg/m2)

while peak vo2 (% predicted) median was 63.15(54.2–77.7) in group one versus 48.65(44.8–68.4) in group two with $p=0.017$ (Table 2, Fig. 6). Peak WR (watt) was statistically significant different between the two groups with median 54.0(42.5–71.0) in group one versus 31.0(6.0–36.0) in group two with $p<0.001$. peak WR(%predicted) was also significant different between the two groups with median 32.17(25.4–47.2) in group one versus 17.90(5.1–24.8) in group two with $p<0.001$ (Table 2, Fig. 7).

Regarding hospitalization and ER visits, there was statistically difference regarding hospitalization $p<0.001$, patients in group two had more frequent hospitalization than group one with median 3(2.0–5.0) versus 2(2.0–3.0) respectively (Table 2, Fig. 8).

Discussion

Vital results were reported in this investigation. Patients with reduced peak O2P had reduced exercise capacity and increased hospitalizations for COPD-related complications.

Patients with chronic obstructive pulmonary disease are at greater risk for cardiovascular impairment. Since O2P is a characteristic of SV, it is important to recognize that instances with poor peak O2P may be further worsened by cardiovascular dysfunction [11, 12].

Table 2 Comparison between the two studied groups according to different parameters

	Total ($n=50$)	Group I ($n=16$)	Group II ($n=34$)	Test of Sig	*p*
CV					
CHF	25 (50%)	2 (13%)	23 (68%)	$\chi^2=13.235^*$	$<0.001^*$
CAD	23 (46%)	2 (13%)	21 (62%)	$\chi^2=10.630$	0.001^*
HTN	21 (42%)	6 (38%)	15 (44%)	$\chi^2=0.196$	0.658
Arrhythmia	4 (8%)	0 (0%)	4 (12%)	$\chi^2=2.046$	$^{FE}p=0.292$
Valvular disease	7 (14%)	2 (13%)	5 (15%)	$\chi^2=0.044$	$^{FE}p=1.000$
LVEF (%)					
Mean ± SD	51.42 ± 13.88	58.0 ± 9.26	48.32 ± 14.70	U = 184.0	0.067
Median (Min. – Max.)	50.0(25.0 – 77.0)	60.0(35.0 – 66.0)	44.50(25.0 – 77.0)		
Stroke volume (ml)					
Mean ± SD	49.68 ± 14.61	41.0 ± 11.80	53.76 ± 14.14	U = 135.50*	0.004*
Median (Min. – Max.)	45.50(33.0 – 79.0)	36.50(33.0 – 71.0)	60.0(34.0 – 79.0)		
Peak VO2 (l/min)					
Mean ± SD	1.20 ± 0.51	1.67 ± 0.44	0.98 ± 0.38	U = 55.50*	<0.001*
Median (Min. – Max.)	1.21(0.20 – 2.78)	1.64(0.86 – 2.78)	1.0(0.20 – 2.03)		
Peak VO2 (% predicted)					
Mean ± SD	56.36 ± 20.10	64.56 ± 17.42	52.50 ± 20.34	U = 157.50*	0.017*
Median (Min. – Max.)	50.8 (9.2 – 91.7)	63.15 (34.1 – 91.7)	48.65 (9.2 – 90.2)		
Peak WR (watt)					
Mean ± SD	35.72 ± 25.78	55.44 ± 25.12	26.44 ± 20.56	U = 86.50*	<0.001*
Median (Min. – Max.)	36.0(1.0 – 116.0)	54.0(5.0 – 116.0)	31.0(1.0 – 70.0)		
Peak WR (% predicted)					
Mean ± SD	24.10 ± 21.30	39.17 ± 27.55	17.01 ± 12.92	U = 91.0*	<0.001*
Median (Min. – Max.)	23.8(0.70 – 127.6)	32.17(4.6 – 127.6)	17.9 (0.70 – 53.6)		
Hospitalization					
Mean ± SD	2.40 ± 1.91	0.63 ± 1.15	3.24 ± 1.60	U = 61.50*	<0.001*
Median (Min. – Max.)	2.50 (0.0 – 6.0)	0.0 (0.0 – 4.0)	4.0 (0.0 – 6.0)		
ER visits					
Mean ± SD	3.0 ± 1.56	2.56 ± 0.96	3.21 ± 1.75	U = 228.0	0.346
Median (Min. – Max.)	2.50 (1.0 – 7.0)	2.0 (1.0 – 5.0)	3.0 (1.0 – 7.0)		

SD Standard deviation, *U* Mann Whitney test, χ^2 Chi square test, *FE* Fisher Exact, *p* p value for comparing between the two studied groups

* Statistically significant at $p \leq 0.05$

Group I: Normal Peak O_2 pulse

Group II: Low Peak O_2 pulse

Lung hyperventilation is a potential mechanism behind heart dysfunction in COPD patients. Lung hyperinflation is highly correlated with oxygen saturation pressure, as has been shown in previous research. Increased intrathoracic pressure from hyperinflation reduces venous return, which in turn impairs left ventricular filling and decreases stroke volume (SV). In addition, RV dilatation and higher resistance to RV contraction are both outcomes of pulmonary hypertension. Due to ventricular interdependence, the enlarged RV also causes the left ventricle (LV) to become compressed [13–15].

As a result of the increased pulmonary vascular resistance, RV systolic performance is decreased, and the left ventricle receives less preload. Previous research confirmed the negative effect of pulmonary hypertension on cardiac function and linked low peak O2P in COPD patients to the condition.

In closing, there is considerable comorbidity between heart failure and COPD [12]. The same risk factors, such as smoking, age, and systemic inflammation, apply to both illnesses. Patients with COPD are 2.57 times more likely to experience heart failure than those without COPD.

Patients with COPD and heart failure may have impaired peak oxygen uptake (O2P). In COPD, the ability to exercise (peak VO2) is a critical issue. Patients with

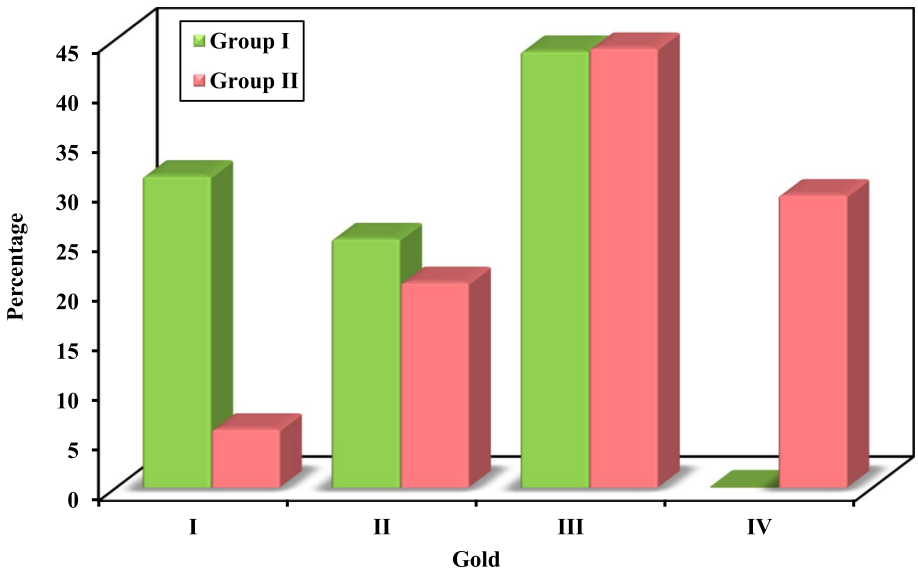

Fig. 3 Comparison between the two studied groups according to gold

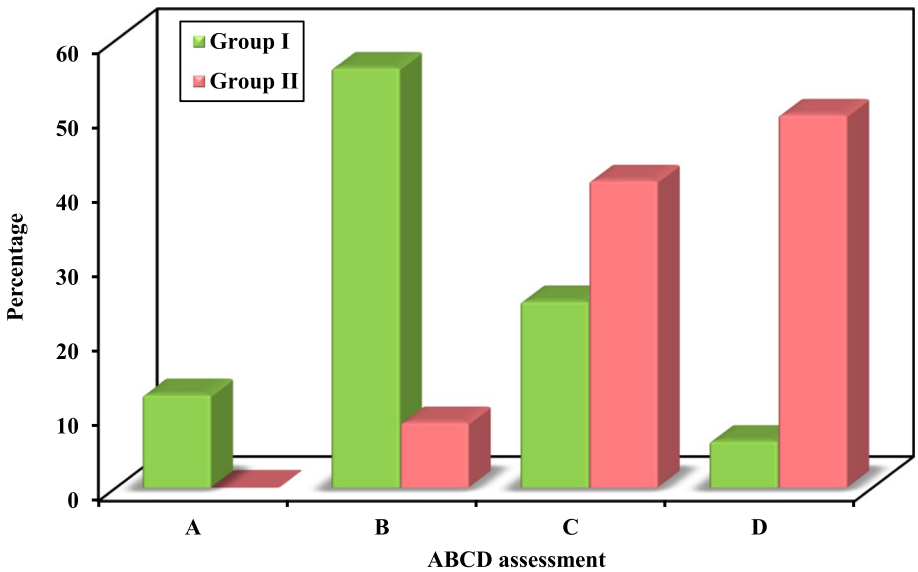

Fig. 4 Comparison between the two studied groups according to ABCD assessment

COPD and heart failure both have peak VO2 as their most important prognostic factor [16, 17].

According to research by Johnson BD et al., an individual's V o2 can increase from its resting value of around 3.5 ml/minute per kilogram (around 250 ml/minute) to values around 15 times the resting value, at around 30–50 ml/minute per kilogram. Over 20 times their resting values (up to 80 ml/minute per kilogram) is possible for athletes [18].

Limitations in oxygen delivery (cardiac output, O2-carrying capacity of the blood), pulmonary limitations (mechanical, control of breathing or gas exchange), oxygen extraction at the tissues (tissue perfusion, tissue diffusion), neuromuscular or musculoskeletal limitations, and effort all contribute to a lower V o2 peak. Low V o2max may not always be the result of a physiologic process as stated by the Fick equation; rather, it may be the result of the patient's own perceptual responses (symptoms). Reduced V o2max can have a variety of causes, and researchers have come to recognize this. V o2max and V o2peak decreases are consequently general indications of diminished exercise capability [19–22].

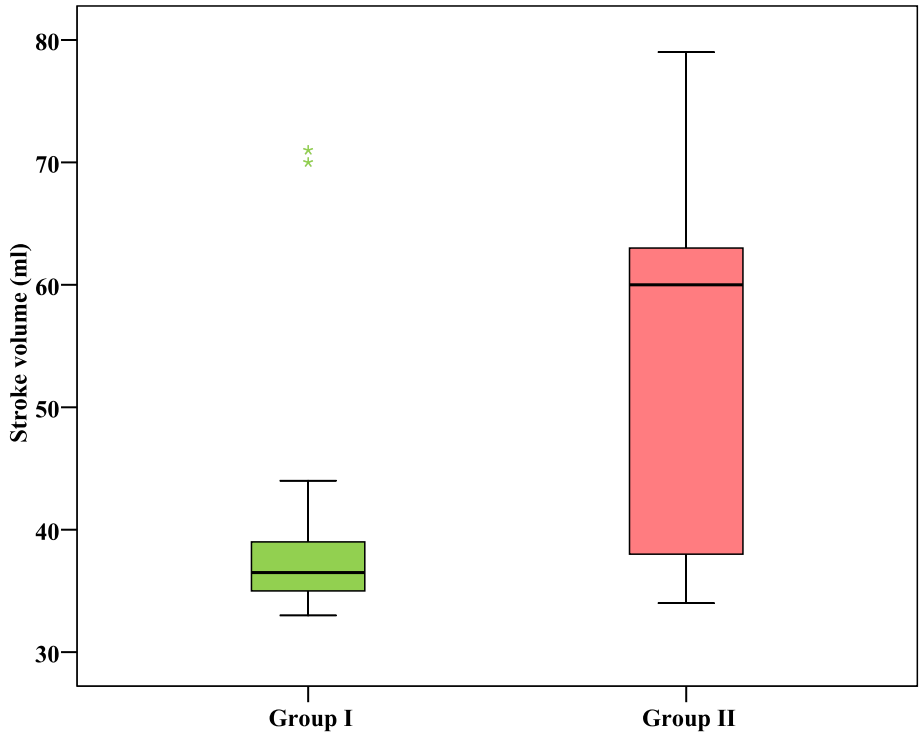

Fig. 5 Comparison between the two studied groups according to stroke volume (ml)

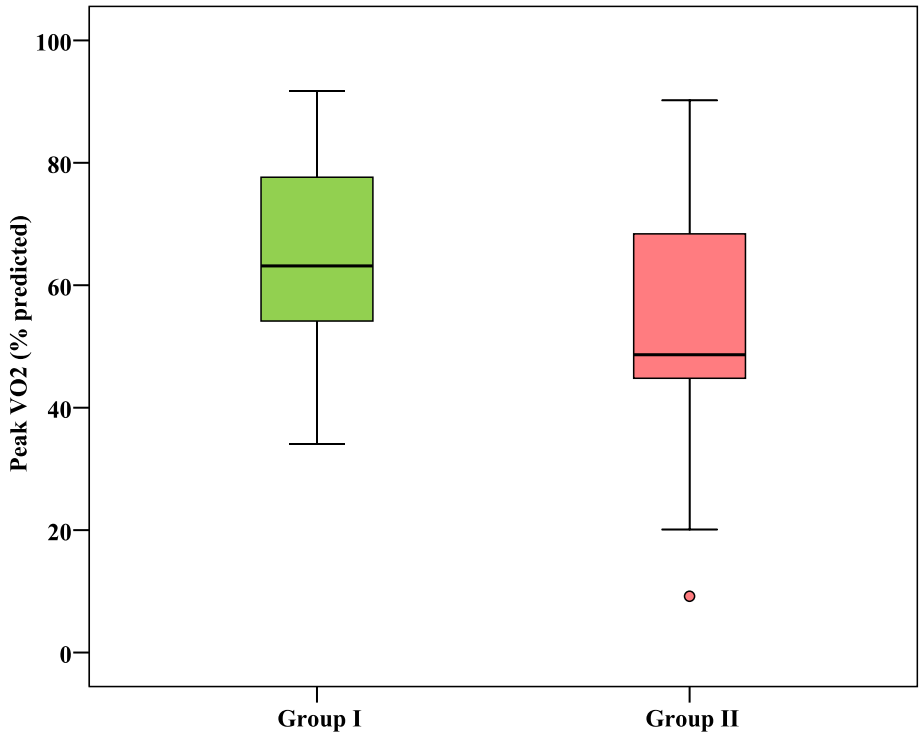

Fig. 6 Comparison between the two studied groups according to peak VO2 (% predicted)

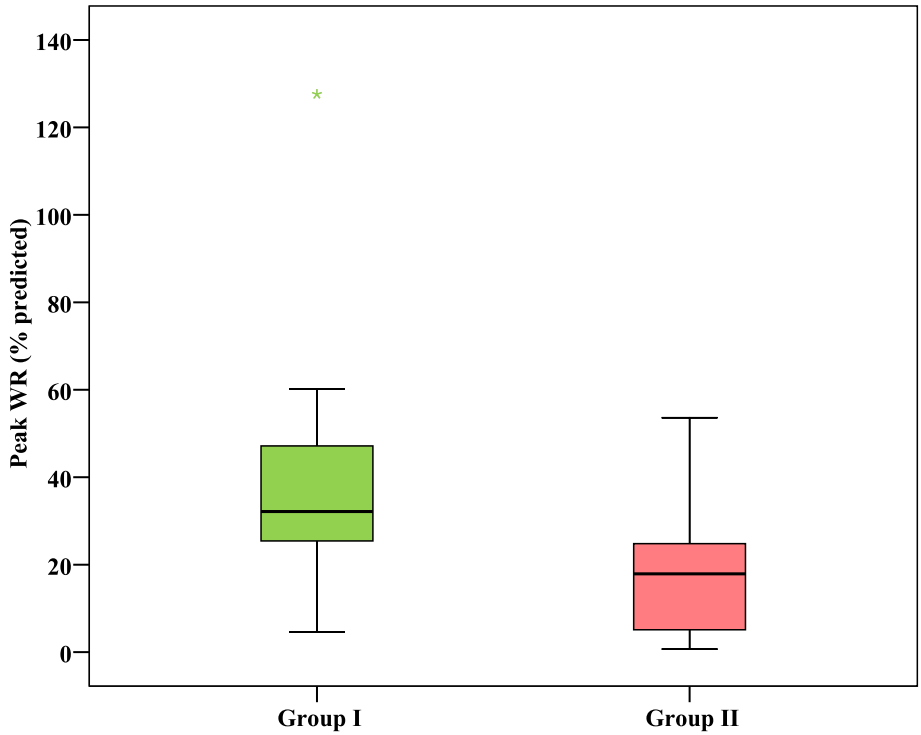

Fig. 7 Comparison between the two studied groups according to peak WR (% predicted)

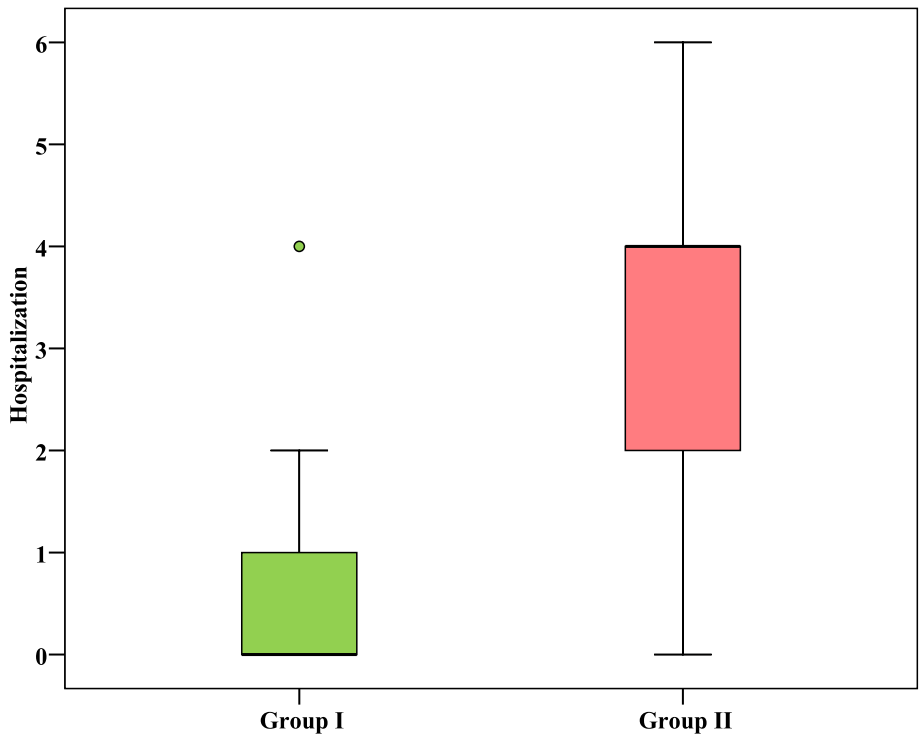

Fig. 8 Comparison between the two studied groups according to hospitalization

In our study, those suffering from moderate to severe COPD had decreased V˙ o2peak and V˙ o2max. We found a correlation between the GOLD staging, ABCD classification and ratio of decrease. The more the reduction in FEV1 the more the reduction in the V˙ o2peak and V˙ o2max and therefore the exercise capacity.

Although patients with mild COPD usually have normal CPET response, some of our studied patients with mild COPD had also decreased V˙ o2peak and V˙ o2max.

Nery LE. et al., Carter R. et al. and Marciniuk DD. et al. had reported those finding before [23–25].

When COPD and heart failure coexist, the results are decreased exercise capacity and increased mortality, as described by Hawkins NM et al. O2P is a crucial measure in chronic obstructive pulmonary disease [17] due to the prevalence of heart failure as a comorbidity.

O2P is a crucial measure in chronic obstructive pulmonary disease (COPD) due to the prevalence of heart failure as a comorbidity. Our findings showed that low peak O2P patients had worse exercise ability, lower HRQL, and more frequent hospitalizations.

Peak O2P affects ventilatory parameters in three primary ways. To begin, there is a connection between lung function and O2P max. Baseline FEV1 was decreased in our study among patients with reduced peak O2P. FEV1 (a ventilatory parameter) was found to have a moderate connection with peak O2P (a circulatory parameter) in patients with COPD.

O2P is inversely associated with lung hyperinflation, and lung hyperinflation is inversely associated with the forced expiratory volume in one second (FEV1 level) [26], which may provide a backwards explanation. Second, peak O2P is correlated with VE; patients with COPD who had impaired peak O2P also had decreased VE during peak exercise. Since O2P decreases with hyperinflation and progressive dynamic hyperinflation during exercise reduces VE, it follows that hyperinflation is detrimental to exercise performance [27].

Third, VEQ represents the patient's ventilatory efficiency and is correlated with peak O2P; individuals with impaired peak O2P have higher VEQ. Patients with reduced peak O2P also had increased VEQ because their hyperinflation and cardiac function were worse. Studies have shown that higher VEQ is associated with a higher risk of death [28, 29].

Significant morbidity and mortality are caused by acute exacerbation of COPD. It is well-established that past episodes of aggravation are predictive of further episodes [1].

Hospitalizations due to COPD were more common among patients with impaired peak O2P in the current study. To the best of our knowledge, peak O2P is an original indicator of worsening. This study provided further evidence for the importance of peak O2P in COPD patients. Patients with poor peak O2P were more likely to experience a severe exacerbation; therefore, we should pay closer attention to lowering risks, such as through adjusting inhaled bronchodilators or corticosteroids, for these patients. To confirm the significance of peak O2P in exacerbation risk, a larger investigation is required.

Conclusions

There was a correlation between reduced peak O2P and subpar exercise capacity and hospitalizations for COPD. When it comes to COPD, peak O2P is crucial since it may serve as an indicator of the severity of lung hyperinflation, pulmonary hypertension, and heart failure.

Abbreviations

CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
CPET	Cardiopulmonary exercise test
FEV1	Forced expiratory volume in one second
HRQL	Health related quality of life
LV	Left ventricle
PO2	Oxygen pulse
RV	Right ventricle
SV	Stroke volume
VE	Minute ventilation
Vo2max	Maximum oxygen consumption

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Authors' contributions

All authors were involved in the revision.

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Declarations

Availability of data and materials

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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