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Peak Exercise Response to Vertical Climbing in Chronic Obstructive Pulmonary Disease Patients

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ABSTRACT

Background: *Stair climbing is an integral component of daily living, which is limited in COPD. To date, stair climbing is used for prediction of VO_{2Max}, pulmonary function, and postoperative complications. The study is designed to understand respiratory limitations and facilitate training.* ***Aim:*** *To correlate peak exercise response to vertical climbing in chronic obstructive pulmonary disease patients.* ***Materials and methods:*** *It was Prospective Correlational study. Fifty COPD patients satisfying the inclusion criteria were included in the study. The patients underwent a stair climb test. Outcome measures were recorded as peak expiratory flow rate (PEFR), respiratory rate (RR), oxygen saturation (SPO_2), heart rate and rate of perceived dyspnoea on Borg scale on pre-and post-test. Mini wright peak expiratory flow meter and hand held pulse oximeter was used to measure PEFR and SPO_2 and HR respectively. Vertical height of floor climbed and time taken to climb was recorded.* ***Results:*** *There was significant increase in HR, RR, dyspnoea score and significant drop in SPO_2 and PEFR on vertical stair climbing with $p<0.05$. A significant negative correlation was observed between vertical height climbed and oxygen saturation ($r=-0.57$). A significant positive correlation was observed between vertical height climbed and respiratory rate ($r=0.31$) and Dyspnoea score on Borg scale ($r=0.31$). No correlation was found between vertical height climbed and PEFR ($r=-0.09$).* ***Conclusion:*** *ΔSPO_2, ΔRR and Δdyspnoea score on Borg scale correlate with vertical height climbed in COPD.*

Keywords: Stair climbing, COPD, exercise response

INTRODUCTION

Chronic obstructive pulmonary disease is a major cause of chronic morbidity and mortality throughout the world [1]. It is multifactorial, reflecting abnormalities of both ventilatory and peripheral muscles and abnormalities in metabolic system in variable combinations [2]. They have reduced performance in daily activities such as walking, stair climbing. It results from complex interaction between central (ventilatory) and peripheral (limb muscles) component of exercise limitation [3]. As ventilatory impairment and peripheral dysfunction is associated with reduced exercise capacity and quality of life, [3] documentation of its relation with performance is likely to be clinically relevant. Dyspnoea is the main reason for referral to pharmacological treatment and respiratory rehabilitation programs in patients with COPD [4]. Hence the understanding of ventilatory limitation remains essential. Stair climbing is a demanding exercise which is also safe and inexpensive, familiar to patients and available to most physician [5]. To date stair climbing is used for prediction of VO_{2max} [5], pulmonary function6 and postoperative complications [6,7]. However, it is not widely employed in COPD. Recently it is studied that the stair climbing is better than 6-minute walk distance in evaluating exercise tolerance in COPD patients after pulmonary rehabilitation [8]. Walking on level surface does not simulate walking up slope in COPD [9]. However, it remains unclear whether 6-minute walk test can predict performance during stair climbing [9]. Hence the present study is designed to assess stair climbing performance of COPD patients and to correlate peak exercise respiratory response to it.

MATERIALS AND METHODS

The study was approved by the Ethics Committee for research on human subjects of the institute. It was a prospective correlational study which was conducted at the physiotherapy center of a multispecialty tertiary care hospital.

Inclusion criteria for the study was patients diagnosed as COPD in accordance to spirometric classification of GOLD guideline who were stable diagnosed by chest physician, defined as no acute exacerbations of pulmonary or cardiac disease for 6 weeks prior to entry into study between age 30-70 years, ambulatory, who can climb independently, not undergoing rehabilitation and who answered 'No' to all questions in physical activity readiness questionnaire. Individuals with known case of cardiac disease, other lung disease, neuro-musculoskeletal disease, vision problems or any other known medical illness was exclusion criteria.

Total 85 patients referred by the chest physician to physiotherapy outdoor patient department at tertiary care hospital, during a six-month period for the study were screened. Total 50 patients satisfying inclusion criteria were included in the study. Remaining patients were excluded because of exacerbations, associated osteoarthritis of knee, rheumatoid arthritis, and cardiac disease. Written informed consent was taken from patients, explaining the study procedure, possible benefits of the study, risks, and discomfort of participating, compensation for participation and study right to withdraw from the study. All patients were on regular prescribed medications for COPD.

Resting parameters (peak expiratory flow rate-PEFR, respiratory rate, oxygen saturation (SPO_2) and heart rate) were recorded prior to test in sitting position. Mini Wright peak flow meter was used to record peak expiratory flow rate. 10 point Borg scale for dyspnoea and leg fatigue, were explained to the patients before the start of test. Then patients underwent a stair climb test. They were instructed to climb as far as possible (maximum 12 flights) at maximal comfortable self-pace, without the use of railings, maintaining speed during ascent and landing and to stop at their maximum, if they complete 12 flights or if they develop symptoms like dyspnoea, leg fatigue, dizziness, or chest pain. First, a practice test was carried out. On next day, stair climbing test was performed. A resting chair was placed on every landing near the stair, where testing was done. Emergency equipment and care were available during test. The test was supervised at all time and a continuous verbal interaction with the patient was maintained to assess the patient's dyspnoea and other symptoms. During the test, pulse rate and oxygen saturation were monitored continuously by means of hand held pulse oximeter with finger probe. Time of climb was monitored with stopwatch. When the patient stopped, number of steps climbed, time taken to complete the test (in seconds), reason for stopping were noted.

Outcome parameters (peak expiratory flow rate, oxygen saturation (SpO_2), rate of perceived dyspnoea and leg fatigue, respiratory rate, heart rate) were recorded immediately post climb, at 3 min after stopping, 6 min after stopping and 9 min after stopping. Recovery time was noted down.

Vertical height of floor climbed by patients was calculated by multiplying number of stairs climbed to height of step.

Each step of the staircase used for the study was measured 16 cm high and 174 cm wide. A climb of 11 steps constituted one flight of stairs which was 1.76 m of vertical height.

RESULTS

Data was analysed using the statistical package for social science version 17.0. Comparison of pre-and post respiratory response on stair climbing was done using student paired t-test. Spearman co-efficient of correlation test was used to correlate respiratory response with vertical height climbed. A $p<0.05$ was considered statistically significant. The 'median' values of dyspnoea score on Borg scale have been taken for analysis.

The mean age of patients was 50.7 years. 86% of the total patients were male. All patients had COPD with mean (± SD) FEV1 of 0.98 (± 0.33L). Two patients were able to climb full vertical height of 21.12 m in mean (± SD) time 113 (± 38.18) sec. Total 24 patients climbed ≥ 10.56 m in mean (± SD) time 88.29 (± 24.08) sec. About 24 patients climbed <10.56 m in mean (± SD) time 58.16 (± 21.58) sec. There was no difference between practice test and second stair climbing manoeuvre in terms of number of stairs climbed and time taken to climb. All patients stopped because of dyspnoea. Around 21 patients stopped because of dyspnoea and leg fatigue. Out of which 15 patients had predominant dyspnoea and 6 patients had predominant leg fatigue

As seen in Table 1, there was significant increase in heart rate ($p<0.05$), respiratory rate ($p<0.05$), dyspnoea score ($p<0.05$) and significant drop in oxygen saturation (SPO_2) ($p<0.05$) and peak expiratory flow rate (PEFR) ($p<0.05$) post exercise test. Oxygen saturation (SPO_2) decreased by 3.06 ± 1.86. Fall in saturation >4% occurred in 9 patients. Patients achieved 57.41% to 83.87% of their age predicted HR_{max}.

Table 1 Comparison of resting and peak exercise response on stair climbing

n = 50	Rest (mean ± SD)	Peak (mean ± SD)	*p-value
HR	86.80 ± 9.6	115.58 ± 10.25	p<0.05
RR	24.40 ± 3.76	38.32 ± 3.98	p<0.05
SPO_2	97.52 ± 1.18	94.50 ± 2.54	p<0.05
PEFR	197.90 ± 81.86	184.92 ± 85.07	p<0.05

Impression: There was statistical significant difference in HR, RR, SPO_2, PEFR, p<0.05.

In Figure 1, a significant negative correlation was observed between vertical height climbed and oxygen desaturation (r=-0.57). The mean (± SD) drop in saturation was 3.06 (± 1.86). In Figures 2 and 3, significant positive correlation was observed between vertical height climbed and respiratory rate (r=0.31) and dyspnoea score on Borg scale (r=0.31). The mean (± SD) rise in respiratory rate and dyspnoea score on Borg scale was 13.92 (± 2.68) and 5 (3-7) respectively. No correlation was found between vertical height climbed and PEFR (r=-0.09) shown in Figure 4. The mean (± SD) drop in PEFR was 10.80 (± 8.53).

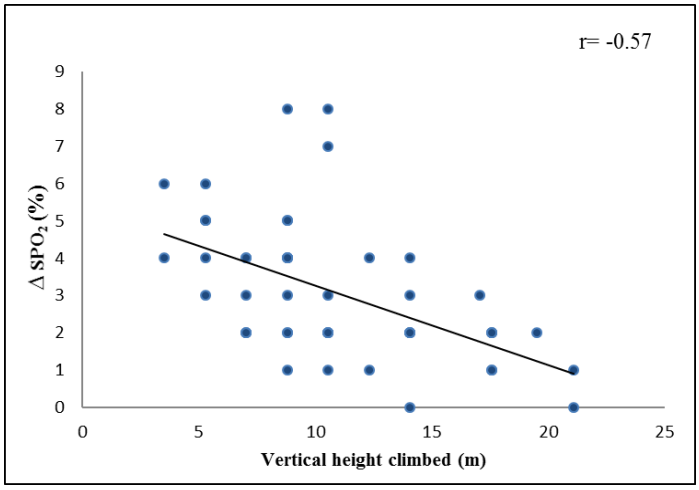

Figure 1 Correlation of ΔSPO_2 to vertical height climbed

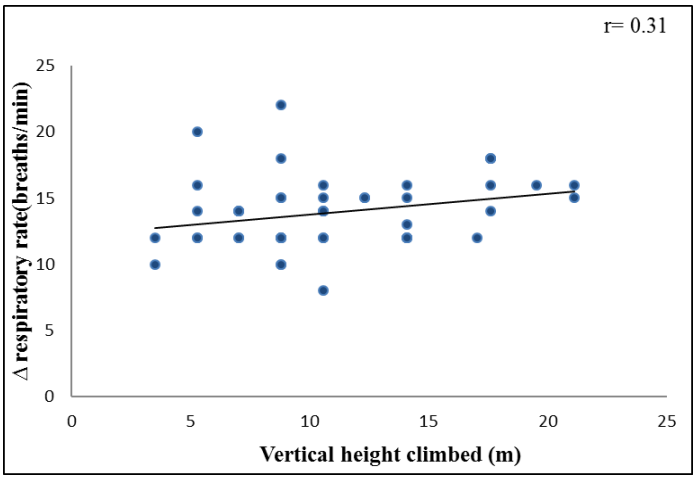

Figure 2 Correlation of ΔRespiratory rate to vertical height climbed

It shows statistical significant correlation with r= 0.31 and p<0.05.

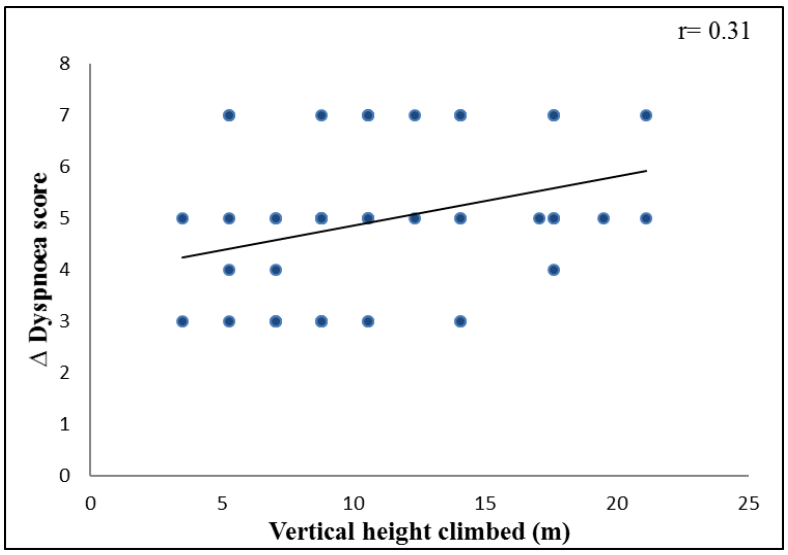

Figure 3 Correlation of ΔDyspnoea Score on Borg scale to vertical height climbed

It shows statistical significant correlation with r=0.31 and p<0.05.

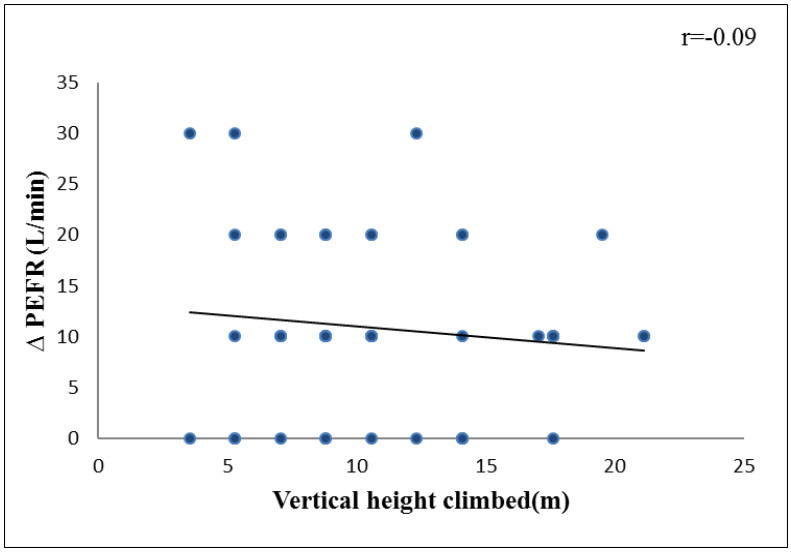

Figure 4 Correlation of ΔPEFR to vertical height climbed

It shows no correlation with r=-0.09 and p>0.05.

DISCUSSION

The result of the study showed that there is significant change in peak exercise response on vertical climbing in COPD patients. The oxygen saturation (ΔSPO_2), respiratory rate (ΔRR) and dyspnoea score on Borg scale correlated significantly to vertical climbing in COPD patients. But not correlated with peak expiratory flow rate (ΔPEFR).

In this study, all patients completed the test without any adverse events. Patients achieve 57% to 84% of their age predicted maximum heart rate (HR_{max}), which was moderate to vigorous exercise intensity. It reflects the stair climbing they performed, was enough demanding to evaluate the cardiopulmonary response.

We found significant correlation between ΔSPO_2 on stair climbing and vertical height climbed (r=-0.57, p<0.001). Alessandro Brunelli, et al. in the study with candidates for lung resection surgery who underwent symptom limited stair climbing test found that the oxygen desaturation has poor correlation with number of stairs climbed up. But it

well correlated with the postoperative complications [10]. The variability of results may be because of different study population taken for study.

The fall in saturation can be explained by the pathophysiologic feature of COPD: Gas exchange abnormalities which worsen during exercise. Destruction of lung parenchyma generates ventilation perfusion imbalance [1]. In addition, COPD have an increased physiological dead space, due to peripheral airway obstruction and a reduced pulmonary vascular bed, that further worsen VA/Q abnormalities [1,11]. During exercise, there is worsening of gas exchange abnormalities and increasing ventilatory demand [1,11].

In COPD, it is found that anaerobic system of metabolism is more predominant. On one hand, it increases $PaCO_2$ on the other hand it imposes the muscle more susceptible to fatigue because of premature muscle acidosis [12]. This explained the finding in our study that some patients (n=21) had associated leg fatigue after climbing up which evolved as one of the limiting factor.

Abnormalities in gas exchange in COPD [1], aging effect [13], muscle metabolism [12] may lead to exercise hypoxemia and desaturation. But the demand placed by the exercise has influence on it. Stair climbing is known to markedly enhance metabolic and ventilatory requirement due to involvement of large muscle groups [14]. Stair climbing requires an increased range of motion of lower limb joints and more intense muscular activity to generate larger forces that vertically translate the body's centre of gravity, as the individual has to work against gravity to ascend [15]. Pollock, et al. stated that symptom limited staircase climbing is safe, simple, and demanding exercise and that may be used to evaluate the cardio pulmonary reserve of stable patients with chronic airway disease [5].

It is found that staircase climbing causes significant decrease in PaO_2 level, increase blood lactate production, pronounced drop in pH in COPD patients [9]. Bruneli, et al. stated that maximum stair climbing test is an intense constant work load exercise, challenging large amount of muscle mass and appears appropriate to elicit oxygen desaturation, which in turn may be a reliable marker of deficits in oxygen transport system [10]. Nikolić, et al. support the finding [7].

Young examined the ventilation on stair climbing and found alveolar ventilation to be less on stair climbing, tending to explain the greater fall in arterial oxygen partial pressure (PaO_2) in normal [16]. Similar findings explained by Oldenburge, et al. in normals, who reported a fall in alveolar oxygen saturation and less alveolar ventilation during stair climbing work. He explained the change in arterial oxygen partial pressure (PaO_2) at the, onset of exercise occurs as a result of complex interaction involved in body stores of oxygen, tissue oxygen consumption, changes in pulmonary ventilation–perfusion relationship, rate of adaptation of alveolar ventilation and cardiac output [17].

Hence the demand of staircase climbing and pathologic abnormalities of COPD, aging effect all contribute to the increasing the ventilatory demand and early termination of exercise.

In this study, we found the significant weak correlation between change in respiratory rate with stair climbing and vertical height climbed by patients. ($r=0.31$, $p=0.02$). There is increased cost of breathing in COPD. During exercise, ventilatory demand increases. So, the minute ventilation should increase to fulfil the ventilatory requirement and to maintain blood gas homeostasis. Hyperinflation reduces the inspiratory capacity needed to increase the tidal volume [18]. Therefore, during exercise increase in respiratory rate is necessary to enhance alveolar ventilation when normal increase in tidal volume is not possible [18]. This shortens the time for lung emptying causing air trapping which leads to the development of dynamic hyperinflation and limits the exercise tolerance [3]. Dreher, et al. in his study found the prolonged dynamic hyperinflation on stair climbing in COPD patients [9]. Pollock, et al. found that minute ventilation (VE) correlated well with number of stair climbed in chronic obstructive airway disease patients [5].

As the exercise was demanding, patients climbed maximum to their capacity. Dyspnoea perception was on higher side (median-5 range: 3-7) irrespective of individual height climbed. Dyspnoea is a term used to characterize a subjective experience of breathing discomfort that is comprised of qualitatively distinct sensations that vary in intensity. The experience derives from interactions among multiple physiological, psychological, social, and environmental factors, and may induce secondary physiological and behavioural responses [4]. As it is a subjective perception might be weakly correlated with vertical height climbed.

The more sophisticated means of measurement of ventilation (maximum voluntary ventilation, minute ventilation) and dynamic hyperinflation (inspiratory capacity, end expiratory lung volume) were not studied to reveal their correlation

to vertical climbing. Further study can be done using these measures. Peripheral muscle dysfunction also contributes to the activity limitation. Further research on this topic should be done studying correlation of peripheral muscle functions (strength, endurance) to vertical climbing [19].

CONCLUSION

The oxygen desaturation, respiratory rate and dyspnoea score on Borg scale correlated to vertical climbing in chronic obstructive pulmonary disease patients. These measures are easily available clinically. Therefore, the correlation of these measures with patient's performance can be used to evaluate exercise tolerance in COPD patients before and after pulmonary rehabilitation. It will be helpful for planning individual pulmonary rehabilitation programme and hence facilitate training.

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