Original Article

Indian Journal of Physiotherapy and Occupational Therapy
Volume 16 No. 4, October-December 2022

Physiological Cost Index among Individuals with Mild to Moderate Chronic Obstructive Pulmonary Disease and their Compliance with Pulmonary Rehabilitation

Namratha Shanbhag[1], Sangeeta Appannavar[2], Vijayalaxmi S Kathare[3], Tulasi H Kulkarni[4]

[1]MPT in Cardiorespiratory Disorders, [2]Assistant Professor, [3,4]MPT in Cardiorespiratory Disorders, Shri Dharmasthala Manjunatheshwara College of Physiotherapy, Sattur, Dharwad, Karnataka, India.

How to cite this article: Namratha Shanbhag, Sangeeta Appannavar, Vijayalaxmi S Kathare et. al. Physiological Cost Index among Individuals with Mild to Moderate Chronic Obstructive Pulmonary Disease and their Compliance with Pulmonary Rehabilitation. Indian Journal of Physiotherapy and Occupational Therapy.

Abstract

Background: Chronic obstructive pulmonary disease is currently one of the top three causes of mortality globally, with poor and middle income nations accounting for 90% of all deaths. The physiological cost index is a technique for calculating the energy cost using the measurement of heart rate.

Aim: To evaluate Physiological cost index among patients with chronic obstructive pulmonary disease and to check their compliance with pulmonary rehabilitation protocol and to rate their exertion using modified Borg scale.

Methodology: A total of 30 participants were included in this study. Subjects were asked to walk for 6 mins at comfortable walking speed and Physiological cost index was calculated by using the walking heart rate. The Physiological cost index were studied on two occasions, before and after performing the given exercises, included upper and lower mobility exercises along with breathing exercises.

Results: Data was analyzed using statistical software R software version 4.1.2. P-value less than equal to 0.05 was statistically significant.

Conclusion: This study found that the Physiological Cost Index of subjects with Chronic Obstructive Pulmonary Disease was seen to decrease after performing the prescribed exercises, suggesting a favorable reduction in energy consumption and improving their functional performance.

Keywords: Chronic Obstructive Pulmonary Disease (COPD), Forced Expiratory Volume in 1 second (FEV1), Global Initiative for Chronic Obstructive Lung Disease (GOLD), Modified Borg Scale (MBS), Physiological Cost Index (PCI), Pulmonary Rehabilitation (PR).

Corresponding Author: Namratha Shanbhag, MPT in Cardiorespiratory Disorders, Shri Dharmasthala Manjunatheshwara College of Physiotherapy, Sattur, Dharwad, Karnataka, India.

Introduction

One of the main causes of death and morbidity worldwide is chronic respiratory illness. Among chronic respiratory diseases, asthma and Chronic Obstructive Pulmonary Disease (COPD are the two most common.[1] A variety of diverse factors and mechanisms contribute to the pathophysiology and clinical manifestation of COPD, making it a complicated disorder.[2] Acute symptoms of COPD, a chronic condition marked clinically by increasing dyspnea, cough and sputum production, and increased sputum purulence, may periodically worsen.[3]

It is believed that the pathophysiology of COPD is based on lung inflammation brought on by exposure to inhaled particles and gases. Inflammatory cells are drawn to and activated in the lung as a result of exposure to these inhaled particles. The disease's major characteristics are mucus hypersecretion, small airway remodeling and constriction, and damage of the lung parenchyma, which cause coughing, air trapping, and increasing ventilation and perfusion mismatch.[4,5]

According to the degree of airflow limitation as indicated by Forced Expiratory Volume in 1 second (FEV1), the Global Initiative for Chronic Obstructive Lung Disease (GOLD) approach categorized COPD as follows:

Stage 1 (mild; FEV1 ≥ 80% predicted)

Stage 2 (moderate; FEV1 ≥ 50% and < 80% predicted)

Stage 3 (severe; FEV1 ≥ 30% and < 50% predicted)

Stage 4 (very severe; FEV1 < 30% or < 50% predicted with chronic respiratory failure).[6]

Patients with COPD engage in less exercise owing to skeletal muscle dysfunction, which is caused by deconditioning and affects skeletal muscle performance (strength and endurance) and structure (fibre size, fibre type distribution, capillary density, and metabolic capacity).[7]

The quantity of 'energy' or calories a person needs/burns to perform any physical or biological activity, such as breathing, flowing blood, digesting food, or moving, is referred to as energy expenditure.[11] The efficacy of walking systems is commonly assessed by measuring the energy consumption of walking.[8] MacGregor founded Physiological Cost Index (PCI) after seeing the need for an easy to use, non-invasive way of calculating the physiological cost of walking that could be used in clinical settings.[10]

PCI is calculated by using the formula: PCI (beats/min) = (Walking heart rate – Resting heart rate)/ Speed (m/min).[11]

By determining the energy cost of walking, over a 6-min walk test (6 MWT), PCI is a quick, safe, and inexpensive method which can be used for many different purposes such as evaluating orthoses, effects of anti-inflammatory drugs, and measuring the severity of diseases.[11,9]

Although there were a few studies that evaluated PCI in COPD individuals, most of them were centered on energy expenditure of walking i.e PCI after breathing exercises. Our literature search did not demonstrate any study which evaluated PCI among individuals with GOLD staging criteria, specifically stage 1 and stage 2, and their response to Pulmonary Rehabilitation (PR). PR has proven to be an integral part in the management of COPD to improve dyspnea and fatigue, exercise tolerance, health related quality of life and reduced hospital admissions. Hence the need of the study is to observe changes in the PCI, post PR among COPD patients and to observe changes their exertion using Modified Borg Scale (MBS).

A study with an objective to provide an update about COPD was conducted in the year 2016 by Sean O'Reilly. It was stated that COPD is a common, preventable, and treatable disease which is characterized by persistent airflow obstruction associated with enhanced inflammation in the airways and the lungs in response to noxious particles or gases. He also mentioned that clinical history and pulmonary function testing are necessary for accurate diagnosis. While exposure to tobacco smoke remains a common cause, other aetiologies and underlying genetic predisposition play significant roles. There are many different treatment choices, and each one should be customised based on the symptoms and frequency of exacerbations.[4]

A literature review was done in the year 2018 regarding exercise assessments and trainings of PR in COPD. In COPD patients, skeletal muscle weakness results in decreased activity. PR, a crucial component of managing COPD, lessens dyspnea and exhaustion, enhances exercise tolerance and health related quality of life, and lowers hospital admissions and death for COPD patients. The primary element of PR, which consists of exercise assessment and training therapy, is exercise. To evaluate PR's application in clinical practice, this article summarized the common methods of exercise measurement and exercise training for patients with COPD. Exercise evaluations should take into account a patient's symptoms, strength, endurance, and health related quality of life. Following calculations, comprehensive exercise programmes that may include endurance, strength, and respiratory training should be designed. More studies are warranted to support the evidence and examine the effects of long term benefits of exercise training for patients with COPD in each stage.[7]

A study was done to find out if PCI can be calculated using MacGregor's Equation in the year 2015. In this study a total of 50 young randomly selected healthy females performed 50m, 100m and 150m walking test at their self-selected preferred speed. A 100-meter walk at speeds slower and faster than the ideal speed yielded the PCI, too. Using MacGregor's equation, the PCI during exercise was computed by taking into account heart rate and walking pace over a range of distances. The PCI values increased significantly when subjects walked either slower or faster than their normal preferred speed. The results showed that the physiological cost index values were consistent over a range of walking distances. When respondents walked at their chosen speed, the PCI was the lowest, and it rose when they walked more slowly or more quickly. The first estimation was higher than subsequent estimations.[9]

Materials and Methods:

This was a prospective cohort study aiming to find out PCI in COPD patients and their compliance with PR.

Inclusion Criteria:

1. Patients diagnosed with COPD by a qualified medical practitioner.
2. Patients with mild to moderate COPD according to GOLD criteria.
3. Patients of age group 45 – 65 years of age.

Exclusion Criteria:

1. Patients with acute exacerbation and GOLD staging of 3 and 4 COPD.
2. Patients who are suffering with any lung pathology secondary to post covid infection or secondary to any restrictive lung pathology/ any traumatic injury/ neurologic factor etc.
3. Patients with existing cardiovascular or neurological conditions.

The subjects were recruited using convenient sampling method. Patients visiting Medicine and Pulmonology OPD in SDM hospital, Dharwad (Dec 2021 - June 2022) who have been diagnosed with mild to moderate COPD were included as per the inclusion and exclusion criteria. Subjects were asked to complete the 6 minute walk test. MBS for rate of perceived exertion was recorded. PCI was obtained after the subject had completed 6 min walk test, after which subjects were made to perform a set of exercises which included 10 min warm up period, 25 min of aerobic activity and 10 min of cool down period. Aerobic activity included diagonal arm raises, arm abduction into elevation and reverse, and arm abduction, forward flexion, and reverse; step-ups with three step heights; and straight leg raises along with a walking program with nine levels, the maximum level being 10 min of rest and then 10 min of walking.[12]

In addition to this Diaphragmatic breathing and pursed lip breathing exercise were included.19 The same set of exercises was given to the subject and was told to perform for 6 weeks. Dosage of exercise: Frequency of 3 – 5 times a week with a duration of 20 minutes performed twice a day. Patient was evaluated for their PCI after 6 weeks of follow up.

Data was analysed using statistical software R software version 4.1.2 and Microsoft Excel. Categorical variables are presented as a frequency table. Continuous variables are expressed as

Mean±SD/Median (minimum, maximum). For normally distributed variables paired t-test was used to compare the mean of variables between the time points. For non-normally distributed variables Wilcoxon Signed Rank test used to compare the distribution of variables between the time points. Shapiro-Wilk's test used to check the normality of variables. P-value less than equal to 0.05 is statistically significant.

Results and Discussion

The study had 30 participants. In the study, mean age observed was 57.07±6.42 years and 45 years and 65 years were the minimum, maximum years of age observed respectively. There were 19 males in the study. Out of 30, 21 (70%) had normal Body Mass Index (BMI) levels.

Table 1: Comparison of variables over time.

Variables	Time point		p-value
	Pre	Post	
RHR	89±4.19 89 (80, 99)	86.67±3.8 86 (78, 98)	<0.0001^{WS}
Distance (in meter)	278.67±33.96 277.5 (220, 350)	289.33±35.23 290 (225, 365)	<0.0001*^{pt}
WHR	109.73±7.05 110 (96, 122)	105.83±6.68 106 (92, 118)	<0.0001*^{pt}
Walking Speed	46.44±5.66 46.25 (36.67, 58.33)	48.22±5.87 48.33 (37.5, 60.83)	<0.0001*^{pt}
SPO_2 (%)	96.87±0.9 97 (96, 99)	97.63±0.89 98 (96, 99)	<0.0001*^{WS}
MBS	3.13±0.82 3 (2, 4)	2.25±0.77 2 (0.5, 3)	<0.0001*^{WS}
PCI	0.46±0.13 0.45 (0.21, 0.76)	0.4±0.13 0.4 (0.18, 0.68)	<0.0001*^{pt}

Abbreviations: WS: Wilcoxon's Signed rank test, pt: Paired t-test.

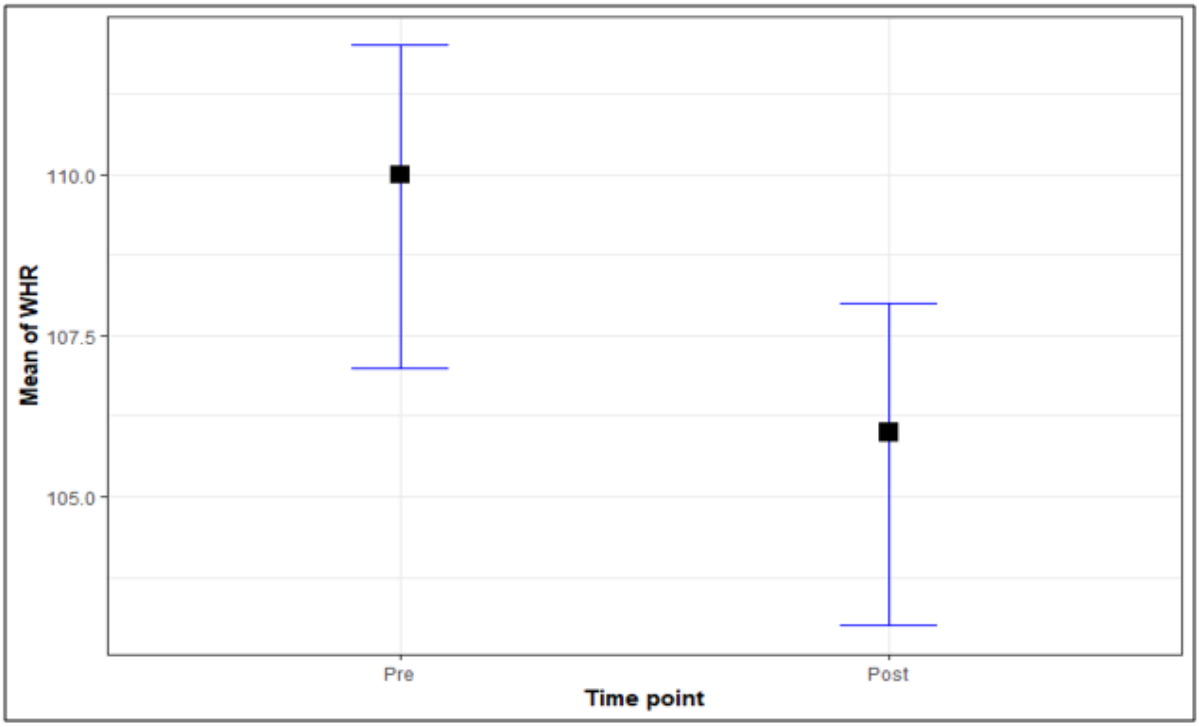

Figure 1: Mean of Walking Heart Rate (WHR) over time point.

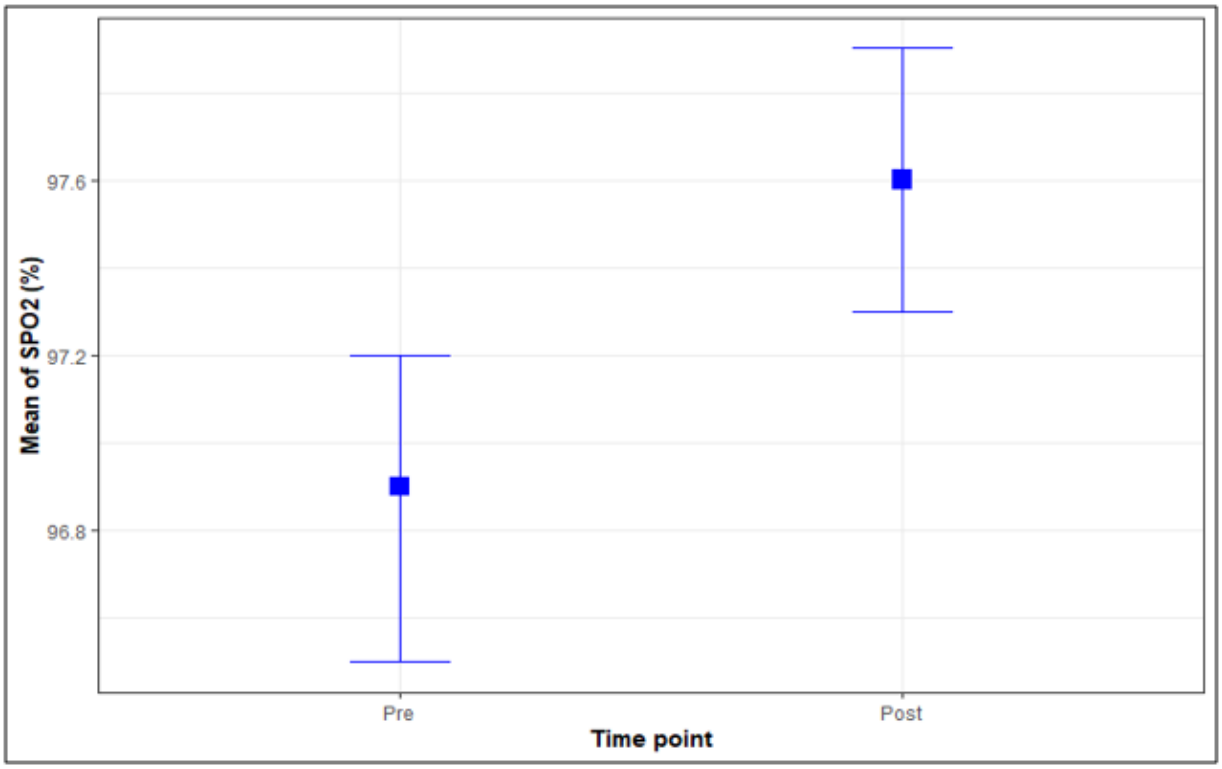

Figure 2: Mean of SPO2 (%) over time point.

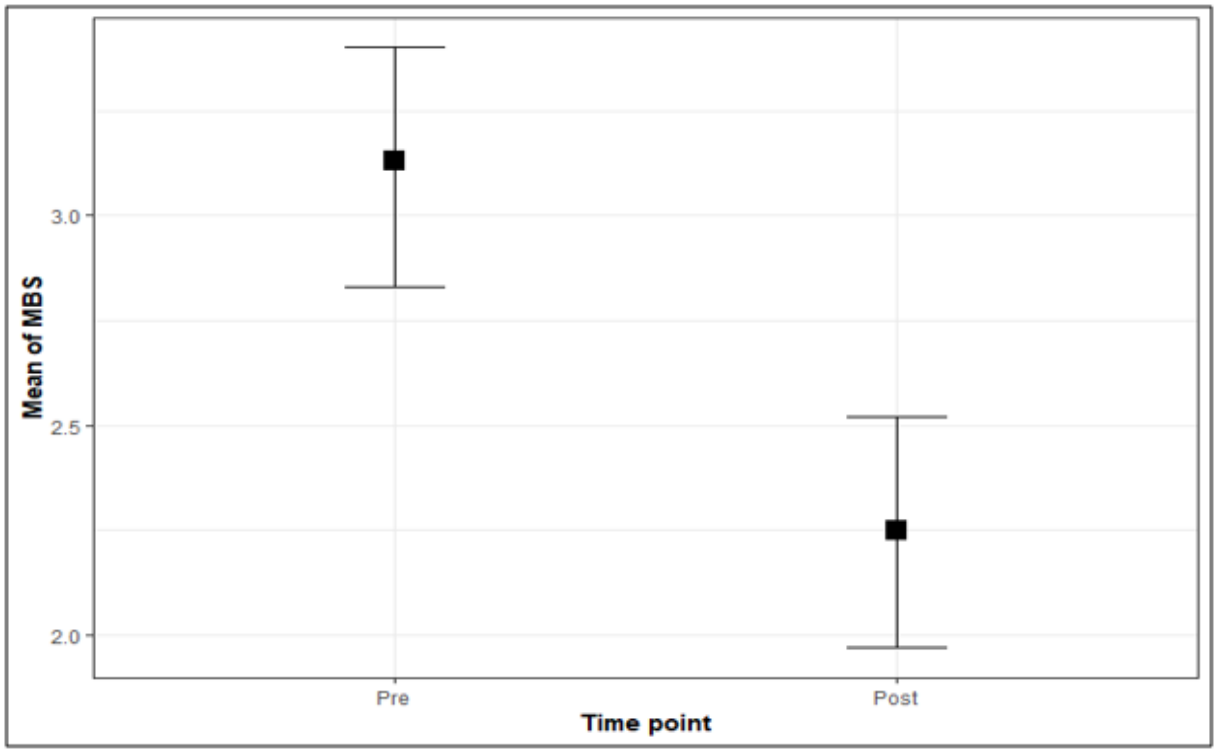

Figure 3: Mean of Modified Borg Scale (MBS) over time point.

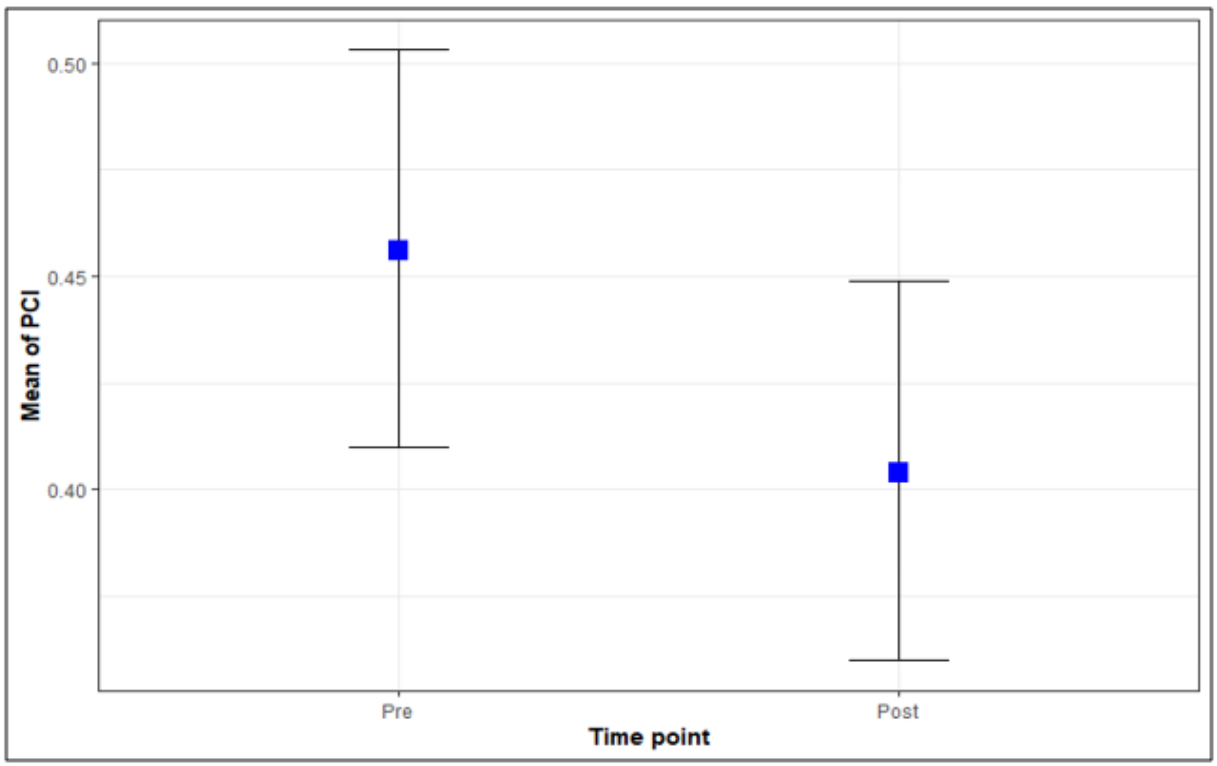

Figure 4: Mean of Physiological Cost Index (PCI) over time point.

The study was conducted with an objective to assess PCI in COPD individuals, after a period of 6 weeks and to check whether compliance of PR protocol influenced PCI. This study was carried out with a prospective cohort design. The demographic details of each subject were noted. A total of 30 subjects with mild to moderate COPD, according to GOLD staging criteria, were included in the study, of which 19 were male and 11 were female.

Patients with COPD experience an increase in heart rate during both rest and activity due to this increased effort of the heart. In our study, it was observed that all the patients had a considerable decrease in their resting heart rate after performing breathing exercises. This observation can be correlated with a study conducted by Gosselink which states that deep breathing exercises which included diaphragmatic breathing and pursed lip breathing resulted in decrease in heart rate, respiratory rate, anxiety and dyspnoea.[13]

After engaging in breathing exercises, the stress and mechanical effort of breathing will decrease. This lessened physiological effort required for breathing which could have resulted in a lower resting heart rate.

Our study included two types of breathing exercises, pursed lip breathing and diaphragmatic breathing. Diaphragmatic breathing technique has shown to improve ventilation and oxidative stress among COPD patients.[14]

An author, Gail, reviewed that pursed lip breathing slows the respiratory rate and that there is evidence to suggest that doing so may lessen the resistive pressure drop across the airways and, as a result, may lessen airway narrowing during expiration. The reduced dyspnea some people experience when adopting this technique may be caused by this decrease in airway constriction.[18]

All of these factors improved the oxygen flow to the working muscles, enabling the patients to walk more distance right away after engaging in breathing exercises. This can be correlated to increase in walking speed observed in these patients after a 6 week period. As discussed above, these changes may be contributing for the decreased PCI values post intervention.

In our study we included a set of exercises with 10 min warm up period, 25 min of aerobic activity and 10 min of cool down period. Aerobic activity included diagonal arm raises, arm abduction into elevation and reverse, and arm abduction, forward flexion, and reverse; step-ups with three step heights; and straight leg raises, as a part of PR. It was observed that this PR program helped in improving the exercise tolerance of these patients, which in turn helped in improving dyspnea and decreasing their overall work of breathing. This contributed significant changes in PCI. This observation is in concurrence with a study by James Patrick Finnerty, Iain Keeping, Irene Bullough, Julie Jones, who studied the effectiveness of outpatient PR in chronic lung disease.[12]

An uncontrolled study found that 5 hours per week of exercise training and knowledge intake over a period of six weeks was linked to a significant increase in shuttle walking distance that persisted for six months.12 With an outpatient programme of as little as 1.5 hours per week of supervised teaching, breathing practice, and exercises, 44 individuals with COPD in another uncontrolled research demonstrated a significant improvement in dyspnea.12 Considering these guidelines, we incorporated a PR program with a frequency of 3 – 5 times a week, for a duration of 20 minutes, performed twice a day, for our study.

Our study found that, at baseline, the average PCI increased as the age group increased. Post intervention, there was a significant decrease in the PCI suggestive of decreased oxygen uptake.

Individuals' walking speeds tend to slow down as they get older. As a result, PCI increased and an individual's distance travelled decreased, resulting in a higher energy cost. In patients with COPD who were doing a 6-minute treadmill walk, Belman et. al.[15] discovered that the MBS was a reliable technique for assessing dyspnea.[16]

Wilson and Jones evaluated the measurement of dyspnea in healthy young volunteers during exercise using a visual analogue scale and the MBS.17 Similar findings were made by these researchers, who found a strong association between exercise-related employment and the degree of breathlessness as measured by the modified Borg scale.[15] Our study used modified Borg scale to understand rate

of perceived exertion before and after 6 weeks of exercise protocol. It was observed that there was a significant decrease in the rate of perceived exertion post PR.

Conclusion

The Study concludes that PCI was seen to decrease in individuals suffering from COPD after a prescribed PR protocol. Also, there was significant improvement in their rate of perceived exertion using MBS.

Limitations of the study:

1. This study could be conducted on a larger sample size which was a constraint we faced due to the on-going pandemic.
2. The study population were recruited from only one hospital.
3. This study lacked a control group which can be considered in future.

Future scope of the study:

1. Further research can be done to identify the exercise that will be most helpful to patients undergoing PR by analysing the changes in energy expenditure following specific exercises.
2. Increasing public awareness of PR and involvement.
3. A multi-centered study can be carried out in order for the findings to be generalizable to a broader population.

Ethical clearance: Institutional Ethics Committee, SDM College of Dental Sciences and Hospital, Dharwad

Source of funding: Self

Conflict of interest: None

References

1. Soriano JB, Abajobir AA, Abate KH, Abera SF, Agrawal A, Ahmed MB, et al. Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet Respir Med. 2017;5(9):691–706.
2. Singh D, Agusti A, Anzueto A, Barnes PJ, Bourbeau J, Celli BR, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease: The GOLD science committee report 2019. Eur Respir J. 2019;53(5).
3. Kim V, Aaron SD. What is a COPD exacerbation? Current definitions, pitfalls, challenges and opportunities for improvement. Eur Respir J. 2018;52(5).
4. O'Reilly S. Chronic Obstructive Pulmonary Disease. Am J Lifestyle Med. 2017;11(4):296–302.
5. Hogg JC, Timens W. The pathology of chronic obstructive pulmonary disease. Annu Rev Pathol Mech Dis. 2009;4:435–59.
6. Welte T, Vogelmeier C, Papi A. COPD: Early diagnosis and treatment to slow disease progression. Int J Clin Pract. 2015;69(3):336–49.
7. Zeng Y, Jiang F, Chen Y, Chen P, Cai S. Exercise assessments and trainings of pulmonary rehabilitation in COPD: A literature review. Int J COPD. 2018;13:2013–23.
8. Vllasolli TO, Orovcanec N, Zafirova B, Krasniqi B, Murtezani A, Krasniqi V, et al. Physiological cost index and comfort walking speed in two level lower limb amputees having no vascular disease. Acta Inform Medica. 2015;23(1):12–7.
9. Rana BSJB, Pun M. Estimation of Physiological Cost Index as an Energy Expenditure Index using MacGregor ' s Equation. JNMA J Nepal Med Assoc. 2015;53(3):174–9.
10. Parekh DN. Comparison of Physiological Cost Index during Treadmill Walking in Individuals having Different Body Mass Index. J Med Sci Clin Res. 2019;7(2):737–44.
11. Mehta JN, Gupta A V, Raval NG, Raval N, Hasnani N. Physiological cost index of different body mass index and age of an individual. Natl J Physiol Pharm Pharmacol. 2017;7(12).
12. Finnerty JP, Keeping I, Bullough I, Jones J. The effectiveness of outpatient pulmonary rehabilitation in chronic lung disease: A randomized controlled trial. Chest [Internet]. 2001;119(6):1705–10. Available from: http://dx.doi.org/10.1378/chest.119.6.1705
13. Gosselink RAAM, Wagenaar RC, Rijswijk H, Sargeant AJ, Decramer MLA. Diaphragmatic breathing reduces efficiency of breathing in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 1995;151(4):1136–42.

14. Marotta N, Demeco A, Moggio L, Marinaro C, Pino I, Barletta M, et al. Comparative effectiveness of breathing exercises in patients with chronic obstructive pulmonary disease. Complement Ther Clin Pract [Internet]. 2020;41(May):101260. Available from: https://doi.org/10.1016/j.ctcp.2020.101260
15. Kendrick KR, Baxi SC, Smith RM. Usefulness of the modified 0-10 Borg scale in assessing the degree of dyspnea in patients with COPD and asthma. J Emerg Nurs. 2000;26(3):216–22.
16. Belman MJ, Brooks LR, Ross DJ, Mohsenifar Z. Variability of breathlessness measurement in patients with chronic obstructive pulmonary disease. Chest. 1991;99(3):566–71.
17. Wilson RC, Jones PW. A comparison of the visual analogue scale and modified Borg scale for the measurement of dyspnoea during exercise. Clin Sci. 1989;76(3):277–82.
18. Dechman G, Wilson CR. Evidence underlying breathing retraining in people with stable chronic obstructive pulmonary disease. Phys Ther. 2004;84(12):1189–97.
19. S A, D'Sa IP, C K MF, V A, Namboothiri S. Physiological Cost Index (PCI) in Patients with Chronic Obstructive Pulmonary Disease (COPD) before and after giving two commonly used Breathing Exercises. Int J Curr Res Rev. 2011;03(12):41–8.