DOI: 10.7860/JCDR/2022/60252.17149

Original Article

Physiotherapy Section

Physiological Cost Index of Walking among Non Smokers, Smokers and Smokers with Chronic Obstructive Pulmonary Disease- An Observational Study

PARKAVI KUMARESAN[1], UMARANI RAVICHANDRAN[2], JOHN WILLIAM FELIX[3], KARTHIK VIJAYAN[4]

ABSTRACT

Introduction: Most of the Chronic Obstructive Pulmonary Disease (COPD) patients are smokers and their disease progresses with increasing age. The energy cost of walking has strong association with aging and cigarette smoking. Its implication in COPD remains unclear.

Aim: To evaluate the Physiological Cost Index (PCI) of walking among non smokers, smokers and smokers with COPD and to find its association with age and duration of cigarette smoking.

Materials and Methods: The cross-sectional study was carried out in the Department of Physical medicine and Rehabilitation (PMR) at Rajah Muthiah Medical College and Hospital, Annamalai University at Chidambaram, Tamil Nadu, India, from November 2019 to February 2020. The PCI was carried out in 77 males, aged between 50-75 years with body mass index between 18.5-24.9 kg/m^2. There were 24 smokers with COPD, 27 were smokers and 26 were non smokers. The evaluation of six minute walk distance, resting, and post walk heart rate was applied in MacGregor's equation to estimate the PCI.

Results: The mean PCI of smokers with COPD was 0.67±0.3 which was significantly (p-value=0.001) higher than those of smokers (0.22±0.07) and non smokers (0.14±0.04). The smokers and non smokers had no significant variation in PCI (p-value=0.122). Age had no association with PCI (p-value=0.213) whereas the duration of smoking years was found to have significant association (p=0.014).

Conclusion: The PCI was found to be significantly higher in smokers with COPD and a significant association was established with years of smoking rather than age.

Keywords: Aging, Cigarette smoking, Energy expenditure

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is characterized by dyspnea, fatigue, and exercise intolerance which greatly influences the quality of life and mortality [1]. COPD is the second most common cause of non communicable disease related death in India [2]. India contributes more than 20% of COPD mortality (556,000) out of a world total of 2,748,000 annually. World Health Organization (WHO) estimates reported that 90% COPD related death occurs in low-income- and middle-income countries [3]. The increase in the burden of COPD is mainly attributed to cigarette smoking in developing countries [3-5].

People with COPD have higher resting oxygen consumption than people without pulmonary disease. The oxygen cost of breathing is amplified from 2% to 10-40% of total oxygen consumption in COPD as the ventilatory pump is working against the dynamic hyperinflation [6]. The metabolic demands of COPD patients to accomplish simple tasks of daily activities involving the upper limb utilizes 50-60% of maximum oxygen uptake [7]. It was also observed that, time spend on walking is less for COPD patients when compared to age-matched individuals [1]. A considerable deterioration of functional mobility occurs in COPD patients due to limited oxygen supply to working muscles [8].

Cigarette smoking has deleterious effects like smoking-related inflammation, cellular stresses, and tissue destruction which plays an inevitable role in lung disease, such as chronic obstructive pulmonary disease [9]. The magnitude of difference in Spirometric pulmonary function parameters between smokers and non smokers is positively correlated with age [10]. Even without the Spirometric evidence of COPD, cigarette smoking has extensive effects on the lung function that potentially impairs the functional ability and quality of life [11,12]. Most of the COPD patients are cigarette smokers and their symptoms get worse on advancing age [5]. In elderly population, functional ability accounts for the health and longevity [13]. The energy production decreases with increasing age and have adverse effects on functional abilities [14]. Increased energy cost of walking compromises a greater portion of total energy available.

Energy cost of walking is gaining its significance as an important predictor of functional performance and is reflected by the average rate of oxygen consumption standardised by gait speed [15]. Gait speed has linear correlation with energy cost and hyperbolic relationship with oxygen uptake (VO_2). Heart rate and walking speed are linearly related to oxygen consumption at sub maximal levels of exercise [14,16]. Usually, the energy expenditure is calculated by collecting the expired gas using expensive equipment and measuring the VO_2 which is often not available in all circumstances [17].

MacGregor in 1979, proposed an empirical alternative to calculate the energy expenditure of walking i.e., the Physiological Cost Index (PCI). PCI manifests the increase in the heart rate from rest during activity which signifies the increase in energy demand thereby an estimate of oxygen consumption that resulted from activity. The PCI reasonably reflects the metabolic demand imposed on walking [18]. The physiological cost index was found to be higher in older adults when compared to younger ones [19].

The present study intends to discriminate the energy cost of walking by evaluating the PCI among non smokers, smokers and smokers with COPD. The study also tries to find the relationship of energy cost of walking with age and years of smoking. The findings may help in understanding the role and contribution of aging and years of smoking in augmenting the energy cost of walking in COPD diseased, thereby adding up the burden on functional ability.

MATERIALS AND METHODS

The cross-sectional study was carried out in the Department of Physical medicine and Rehabilitation at Rajah Muthiah Medical College and Hospital, Annamalai University at Chidambaram, Tamil Nadu, India, from November 2019 to February 2020. The study protocol was approved by the Institutional Human Ethics Committee of Rajah Muthiah Medical College and Hospital (IHEC/596/2019).

Sample size calculation: The sample size was estimated using Power Analysis and Sample Size (PASS) software using One-way Analysis of Variance (ANOVA) at 5 % significance level and 80% power. On analysing the mean values of Forced Expiratory Volume in the first second/Forced Vital Capacity (FEV1/FVC) ratio (91.3, 85.8 and 84.7) from the previous study [20], the required sample size was 23 in each group. Purposive sampling was done.

Inclusion criteria: All male between age 50-75 years with normal body mass index (18.5-24.9 kg/m2), those who can freely ambulate without any aids were included in the study.

Exclusion criteria: Ex-smokers, SpO_2<85%, Resting Heart rate >100 b/min, recent illness/dyspnoeic episodes within past three months, any major surgery within six months, orthopaedic limitation that interrupts walking ability, recent injury or trauma in lower limb, dyspnoea grade 3 and 4 {as per modified Medical Research Council scale), associated lung pathologies like tuberculosis, cor-pulmonale, neurological and psychiatric disorders were excluded from the study.

The study population consisted of 77 male participants, divided into three subgroups as:

- **Non Smokers (NS)** (n=26): NS were those who never smoked actively in their lifetime.
- **Smokers (S)** (n= 27): Current smokers who have smoked daily for at least 10 years and so far not attended a physician for a dyspnoeic episode were recruited as smoker.
- **Smokers with COPD (S-COPD):** S-COPD group was those who had mild to moderate COPD (as per GOLD guidelines) [21] and not quitted smoking completely.

The participants of S and NS group were identified from those who accompanied the outpatients as attendee. The S-COPD group was referred from Medicine Unit for periodical pulmonary function test. All the participants were clearly explained about the purpose and procedure of the study before obtaining their informed written consent.

Study Procedure

Participants were instructed to adjust their clothing comfortably so as to not restrict their walking. All the assessments were made between 9 am to 12 pm. It was ensured that the participants had consumed their breakfast and not any beverages within 1 hour of testing. The resting heart rate of the participants was measured after 10 minutes of relaxed diaphragmatic breathing in an arm rest chair. The participants were allowed to walk in a straight levelled corridor of 50 m length to and fro with bare foot on their own self-selected comfortable pace [22] for a period of six minutes. At the end of 6 minutes, the walking heart rate was measured. A pulse oximeter was used to record heart rate and a pedometer for the distance walked. PCI is the measure of oxygen cost per unit distance. The increase in heart rate due to walking expresses the oxygen cost.

$$\text{The formula for PCI} = \frac{\text{Walking heart rate-Resting heart rate (beats/minute)}}{\text{Speed of Walking (metres / minute)}}$$

The procedure was again repeated after 20 minutes of rest and the reading of the second trial [4, 15] were used to estimate the PCI value.

STATISTICAL ANALYSIS

The study variables were statistically analyzed using Statistical Package for the Social Sciences (SPSS) version 21.0. Descriptive analysis of age, years of smoking, resting heart rate, walking heart rate, speed of walking and PCI were made. Group-wise comparison of heart rate, smoking years and walking speed was made using One-way Analysis of Variance (ANOVA) and Scheffé's test was applied in significant conditions. Since, the PCI value does not follow the normal distribution, Generalized linear model has been adopted to compare the PCI values among groups and to establish the relation of PCI with age and years of smoking. Analysis was made at 5% level of significance.

RESULTS

[Table/Fig-1] shows that the mean age was similar between the groups. The average smoking years was greater in smokers with COPD than S group. Both resting [Table/Fig-2] and walking heart rate [Table/Fig-3] was high in S-COPD group whereas, the difference between S and NS group was insignificant. On Scheffé's analysis, the mean speed of walking was more in NS followed by the S group. The S-COPD group had the least speed of walking [Table/Fig-4].

Variable	Mean±SD	F-value	p-value
Age (years)			
S-COPD	66.25±7.2	0.544	0.583
S	64.59±6.6		
NS	66.23±5.8		
Smoking years			
S-COPD	44.67±9.8	16.54	0.001
S	34.22±8.4		

[Table/Fig-1]: Descriptive statistics and group-wise comparison of age and smoking years.

Groups	Resting heart rate (beats/min) (Mean±SD)	F-value	p-value
S – COPD	79.83±4.6	15.0	0.001
S	73.93±4.1		
NS	74.08±4.2		

[Table/Fig-2]: Comparison of Resting heart rate (beats /minute).

Groups	Walking heart rate (beats/min) (Mean±SD)	F- value	p-value
S-COPD	99.83±5.8	68.44	0.001
S	84.67±5.8		
NS	84.19±4.1		

[Table/Fig-3]: Comparison of walking heart rate (beats /minute).

Groups	Speed of walking (Mean±SD)	F-value	p-value
S-COPD	33.9±10.5	104.05	0.001
S	48.4±5.4		
NS	70.6±10.4		

[Table/Fig-4]: Comparison of speed of walking (meters /minute).

The mean PCI of S-COPD was 0.67 which was comparatively three times higher than the S (0.22) and 4.7 times the PCI of NS (0.14). The generalised linear model was applied for PCI in [Table/Fig-5a]. and it was found that, PCI value of S-COPD differs significantly with NS. Also, it has been observed that, there was no significant difference (p-value=0.122) exists between S and NS group [Table/Fig-5,5a].

Groups	Mean±SD	Minimum	Maximum
S-COPD	0.67±0.33	0.27	1.59
S	0.22±0.07	0.12	0.36
NS	0.14±0.04	0.08	0.28

[Table/Fig-5]: Comparison of Physiological Cost Index (beats/metre).

Parameters	B	Standard Error	Wald Chi-square	df	p-value
(Intercept)	0.144	0.0370	15.178	1	0.001
S-COPD	0.528	0.0534	98.015	1	0.001
S	0.080	0.0518	2.393	1	0.122
NS	0				

[Table/Fig-5a]: Parameter estimates of PCI based on Generalized linear model.

Age and duration of smoking has included as co-variate, the S-COPD and S were compared in [Table/Fig-6] using generalised linear model. The results indicate that the PCI value was higher for the S-COPD compared to the S group after controlling the effects of age and duration of smoking. However, duration of smoking highly influences the PCI level (p-value=0.014) in addition to COPD status irrespective of age (p-value=0.213).

Parameters	B	Standard Error	Wald Chi-square	df	p-value
(Intercept)	-0.550	0.2741	4.032	1	0.045
S-COPD	0.332	0.0654	25.817	1	0.001
S	0				
Age	0.007	0.0054		1	0.213
Smoking years	0.010	0.0041		1	0.014
Scale	0.037	0.0073			

[Table/Fig-6]: Parameter Estimates for age and smoking years with PCI using Generalized Linear Model.
p-value<0.05 was considered as statistically significant

DISCUSSION

Patients with COPD walk less when compared to their age matched individuals. In predicting the exacerbations of ambulating COPD patients, it was noted that older age and low peripheral oxygen saturation are risk factors. Smoking potentially interfere the oxygenation of blood and promotes an obstructive pattern of airway obstruction [12, 22]. It was hypothesised that, the smoking habit and advancing age might flare up the limited functional mobility by increasing the energy cost of walking (PCI) in smokers with COPD.

The present study intended to identify the energy cost of walking using Physiological Cost Index in smokers with COPD, smokers and non smokers. The present study also tried to find out role of age and years of smoking in adding up the energy cost of walking in smokers with COPD. Physiological cost index, unlike six-minute walk test, incorporates the speed component of walking which measures the metabolic demand of walking. Functional tests help in predicting the progress of the disease, future episodes, hospitalisations and general health status of an individual [18].

The PCI was found to be highest in S-COPD, then in smokers and least in non smokers. This was strongly associated with the decrease in the speed of walking. The PCI of smokers with COPD in this study was found to be twice the mean pre-exercise PCI of COPD patients from the study of Ajith S et al., and Gupta S and Amita M, [23,24]. In the latter study, the heart rate variation coincides with the present study but the speed of walking was high due to which the PCI value shows a decrease from the current study [24]. In the present study, the non smokers walked twice the speed of S-COPD and the smokers walked at speed of approximately 50% more than S-COPD and 50% less than the non smokers.

The S-COPD group had significantly higher resting and walking heart rate than smokers and never smokers while the latter two have no such significance which puts the effect of smoking questionable. The mean heart rate variation in S-COPD was twice as much as that of smokers and never smokers which strongly favours the increase in PCI and signifies the oxygen demand met by heart due to walking [18,25].

To furnish the secondary objective a wide age range (50-75 years) was selected. The mean age of the participants was around 65 and did not differ significantly among the three groups and has no association with PCI. Schrack JA et al., reported increase in energy cost of walking and decrease in gait speed only after the age of 65 in healthy individuals [26]. Years of smoking was found to have significant role in increasing the energy cost of walking. The smokers have significantly less duration of smoking years than smokers with COPD which might be reason to remain symptom free. ost of the literature compared any two groups among smokers, COPD and non smokers (healthy) but the present study included all the three groups. This enables to decide the magnitude of increase in PCI due to disease and smoking separately.

Limitation(s)

The present study analysed the smoking habit in terms of years of smoking rather than pack years. Smokers and non smokers were recruited based on the absence of dyspneic symptoms / episodes rather than spirometric evaluation. The co-morbidities like hypertension, diabetes was evenly distributed among the participants and its influences on PCI need to be studied. Further studies considering the non smokers with COPD and parameters like heart rate recovery after 1 minute are recommended to study the detrimental effects of smoking in detail.

CONCLUSION(S)

Physiological cost index of walking seems to be significantly higher in Smokers with COPD. The fact was strongly associated with highest heart rate difference and least speed of walking. The smokers and non smokers had similar heart rate variation. Their speed of walking differs significantly which increases the mean PCI of smokers twice as much of non smokers. It seems that age have no separate effects on PCI in persons with smoking habit. As the age increases, years of smoking also increase. On the other hand, the years of smoking is highly influencing the PCI levels in smokers and smokers with COPD.

Acknowledgement

The authors would like to acknowledge Dr. M. Senthilvelan, Professor and Head, Dr. S. Sudharsan, Professor, Department of Medicine for referring the COPD cases, Dr. Dhanpal Singh, Professor and Head, Department of Physical Medicine and Rehabilitation, for his constant support and all the participants those who willingly participated in the study.

REFERENCES

[1] Furlanetto KC, Bisca GW, Oldemberg N, Anna TJS, Morakami FK, Camillo CA, et al. Step counting and energy expenditure estimation in patients with chronic obstructive pulmonary disease and healthy elderly: Accuracy of 2 motion sensors. Arch Phys Med Rehabil. 2010;91(2):261-67.
[2] Gudi N, Mahmood A, Roy MP, Ravishankar, Nayak P, Verma A. Burden of COPD among population above 30 years in India: Protocol for a systematic review and proposed meta-analysis. Can J Respir Ther. 2021;57:14-17.
[3] Rajkumar P, Pattabi K, Vadivoo S, Bhome A, Brashier B, Bhattacharya P, et al. A cross-sectional study on prevalence of chronic obstructive pulmonary disease (COPD) in India: rationale and methods. BMJ Open. 2017;7(5):e015211.
[4] Bhome AB. COPD in India: Iceberg or Volcano? J Thorac Dis. 2012;4(3):298-09.
[5] Zhang J, Lin X, Bai C. Comparison of clinical features between non-smokers with COPD and smokers with COPD: A retrospective observational study. Int J Chron Obstruct Pulmon Dis. 2014:9 57-63.
[6] Evison H, Cherniack RM. Ventilatory cost of exercise in chronic obstructive pulmonary disease. J Appl Physiol. 1968;25(1):21-27.
[7] Velloso Z, Jardim JR. Study of energy expenditure during activities of daily living using and not using body position recommended by energy conservation techniques in patients with COPD. Chest. 2006;130(1):126-32.
[8] Sanseverino MA, Pecchiari M, Bona RL, Berton DC, Busolli de Queiroz F, Gruet M, et al. Limiting factors in walking performance of subjects with COPD. Respir Care. 2018;63(3):301-10.
[9] Tajbakhsh A, Gheibihayat SM, Mortazavi D, Medhati P, Rostami B, Savardashtaki A et al. The effect of cigarette smoke exposure on efferocytosis in chronic obstructive pulmonary disease; Molecular mechanisms and treatment opportunities. COPD. 2021;18(6):723-36.

[10] Chatterjee S, Nag SK, Dey SK. Spirometric standards for non-smokers and smokers of India (Eastern region). Jpn J Physiol. 1988;38(3):283-98.
[11] Regan EA, Lynch DA, Curran-Everett D, Curtis JL, Austin JHM, Grenier PA, et al. Clinical and radiologic disease in smokers with normal spirometry. JAMA Intern Med. 2015;175(9):1539-49.
[12] Bano R, Mahaganokar AM, Kulkarni NB, Ahmad N, Nighute S. Study of pulmonary function tests among smokers and non-smokers in rural area. Pravara Med Rev. 2009;4(1):11-16.
[13] Barrett TM, Liebert MA, Schrock JM, Cepon-Robins TJ, Mathur A, Agarwal H, et al. Physical function and activity among older adults in Jodhpur, India. Ann Hum Biol. 2016;43(5):488-91.
[14] Cetin E, Muzembo J, Pardessus V, Puisieux F, Thevenon A. Impact of different types of walking aids on the physiological energy cost during gait for elderly individuals with several pathologies and dependent on a technical aid for walking. Ann Phys Rehabil Med. 2010;53(6-7):399-05.
[15] Wert DM, Brach JS, Perera S, Swearingen JV. The Association between Energy Cost of Walking and Physical Function in Older Adults Arch Gerontol Geriatr. 2013; 57(2): 198-03.
[16] Bailey MJ, Ratcliffe CF. Reliability of Physiological Cost Index Measurements in Walking Normal Subjects Using Steady-state, non-steady-state and Post-exercise Heart Rate Recording. Physiotherapy. 1995;81:10.
[17] Parekh N. Comparison of Physiological Cost Index during treadmill walking in individuals having different body mass index. JMSCR. 2019;07(02):737-44.
[18] Raj R, Mojazi AH, Wang H, Nugent KM. The repeatability of gait speed and physiological cost index measurements in working adults. J Prim Care Community Health. 2014;5(2):128-33.
[19] Sawant S, Thakur AM, Yardi A. Physiological Cost Index of Six Minute Walk Test in Different Age Groups 2016. Indian Journal of Physiotherapy. 2016;10(2):109.
[20] Goel V, Singh S, Sood S, Kaur S, Arvind A. Comparison of ventilatory function test among non-smokers, smokers and smoker brick kiln workers. Int J Health Sci Res. 2015;5(9):242-46.
[21] Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: 2022 report. Retrieved from https://goldcopd.org/2022-gold-reports-2/.
[22] Sharma H, Sarkar A. Correlation between six-minute walk test and Physiological cost index in healthy Indian females. International Journal of Science and Research. 2016;5(2).
[23] Ajith S, Peter D'Sa I, Faisal CKM, Anandh V, Namboothiri S. Physiological cost index (PCI) in patients with chronic obstructive pulmonary disease (COPD) before and after giving two commonly used breathing exercises. International Journal of Current Research and Review 2011; 03(12): 41-48.
[24] Smita G, Amita M. Effect of breathing exercises on physiological cost index in patients with chronic obstructive pulmonary disease. 2015(9);2:133-38.
[25] Mehta JN, Gupta AV, Raval NG, Ravai N, Hasnani N. Physiological cost index of different body mass index and age of an individual. Natl J Physiol Pharm Pharmacol 2017;7(12):1313-17.
[26] Schrack JA, Simonsick EM, Chaves PHM, Ferrucci L. The role of energetic cost in the age-related slowing of gait speed. J Am Geriatr Soc. 2012;60(10):1811-16.

PARTICULARS OF CONTRIBUTORS:
1. Research Scholar, Lecturer in Physiotherapy, Department of Physical Medicine and Rehabilitation, Rajah Muthiah Medical College, Annamalai University, Chidambaram, Tamil Nadu, India.
2. Professor, Department of Medicine, Rajah Muthiah Medical College, Annamalai University, Chidambaram, Tamil Nadu, India.
3. Reader cum Statistician, Department of Community Medicine, Rajah Muthiah Medical College, Annamalai University, Chidambaram, Tamil Nadu, India.
4. Research Scholar, Lecturer in Physiotherapy, Department of Physical Medicine and Rehabilitation, Rajah Muthiah Medical College, Annamalai University, Chidambaram, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Parkavi Kumaresan,
Lecturer in Physiotherapy, Department of Physical Medicine and Rehabilitation,
Rajah Muthiah Medical College, Annamalai University, Chidambaram,
Tamil Nadu, India.
E-mail: parkavikarthik2010@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Sep 28, 2022
- Manual Googling: Oct 10, 2022
- iThenticate Software: Oct 21, 2022 (12%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Sep 15, 2022**
Date of Peer Review: **Oct 17, 2022**
Date of Acceptance: **Oct 22, 2022**
Date of Publishing: **Nov 01, 2022**