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RESEARCH ARTICLE

Physiological cost index of different body mass index and age of an individual

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ABSTRACT

Background: The energy expenditure is the amount of energy (or calories) that a person needs to carry out a physical function such as breathing, circulating blood, digesting food, or a physical movement. The method for estimating the energy cost using measurement of heart rate (HR) is the physiological cost index (PCI). **Aims and Objective:** The aim of this study is to measure and correlate the relationship of energy expenditure of a normal healthy individual with different body mass index (BMI) and age. **Materials and Methods:** A total of 115 participants (59 males and 56 females) were included in this study. Written consent form was obtained. Before exercise testing, each participant's was measured that BMI was the standard formula (kg/m^2). Each participant was given rest for 5 min and recorded resting HR. Participants were asked to walk on 30 m straight floor track for 6-min walk test (6 MWT) at the normal speed. Pre-and post-walked vitals were taken, and PCI was calculated by formula. **Results:** There is highly statistically significant relation with age and PCI ($P < 0.05$) as age (40.86 ± 15.56) increases, PCI (0.26 ± 0.11) value was increases. BMI (25.39 ± 4.56) increases, PCI value was increase and not much difference with BMI and distance covered by normal individual in 6 MWT, but adult age group was covered more distance than the older age group. **Conclusion:** The present study concluded that as the age and BMI increases the PCI increases, suggestive of more energy expenditure.

KEY WORDS: Age; Body Mass Index; Physiological Cost Index; Healthy Individuals

INTRODUCTION

Human walking can be described as a method of locomotion. It involves the use of two legs alternatively support and propulsion. Walking involves the walking process where the gait signifies the manner or style of walking. Locomotion is the action of moving from one place to another. Ambulation is the action of walking, moving about. Walking is the complex activity that comprises almost all body structure and functions. Bioengineering techniques such as electromyography, kinetic, and kinematic analyses have been used to investigate human locomotion.[1] Recently, the energy cost of ambulation has also been proved useful in gait research Butler et al. The traditional parameter of measuring has been the oxygen uptake.

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The energy expenditure is the amount of energy or calories that a person needs to carry out a physical function such as breathing, circulating blood, digesting food, or a physical movement. Total daily energy expenditure is the total number of calories that are burnt each day. To prevent weight gain, energy intake or calorie intake must be balanced with energy expenditure. Energy expenditure varies with both among individual and within the same person depending on the circumstance, body weight, walking speed, surface texture, and gradient. Walking requires <50% of oxygen consumption

(VO_2) max in normal participants. VO_2 per time unit expressed as ml/kg/min. Measurement of energy expenditure in humans is required to assess metabolic needs, fuel utilization, and the relative thermic effect of different food, drink, drug, and emotional components.[2] The ability to assess the energy expenditure and estimate physical activity in free-living condition. In many cases, the objective physical activity measurement approaches are also used to predict the energy expenditure. Those based on energy expenditure or oxygen uptake, physical activity level, and metabolic equivalent; those based on heart rate (HR) monitoring.[3]

Oxygen cost per unit distance; VO_2/kg/min divided by walking speed/min, expressed as VO_2/kg/m. One method to assess the energy expenditure during normal activity is designed by Caltrac accelerometer. The previous study was aiming to determine the interinstrument and intersession reliability of the Caltrac and to validate these instruments with measure of oxygen uptake and determine whether Caltrac accurately reflects difference in energy expenditure due to sex, body weight, and speed. The method required pre-training to the participants for around 6 weeks before the actual measurement of the energy expenditure. After 6-week training, the testing consisted of attaching two Caltrac monitors to a belt at the waist over opposite hip. One unit was programed with participant's age, height, mass, and gender to compute energy expenditure based on constant contained in the Caltrac microcomputer. The other caltrac was programed to give the activity count. This procedure was quite time consuming and expensive.[4] Another method to assess energy expenditure is by physical activity monitor (PAM) accelerometer. The instrument is a performance-based instrument to assess the physical activity under free-living conditions. The procedure included the treadmill test and an outdoor test, both at several speeds. In all participants, PAM was attached to the right hip. The energy expenditure was measured using portable metabolic measurements system to evaluate validity.[5] The procedure seemed very cumbersome and exaggerating making participants very tired. Furthermore, the instrument used was expensive and less feasible.

The other method for estimating the energy cost using measurement of HR is the physiological cost index (PCI).[6] The PCI was calculated from the difference in walking HR and resting HR divided by the walking speed. The PCI value reflected the increase in HR required for walking and is expressed as a heartbeat per meter.[7] The method was administered in a clinical situation which is easily accessible, inexpensive, and feasible.[1,8]

The PCI was introduced by MacGregor who recognized a simple, functional, noninvasive method of measuring the physiological cost of walking that could be equally applied in domiciliary and clinical environments. He also suggested that PCI was one of the good indicators of energy cost. Therefore, PCI is an effective tool used to measure the energy expenditure during walking.[7,9] The reliability of the PCI measurements under steady state, non-steady state, and post-exercise condition was evaluated. The PCI is an easy to use valid and reliable measure of energy expenditure and it is recommended as a useful tool for physiotherapist in the assessment and evaluation of functional performance.[10] The 6-min walk test (6 MWT) is submaximal test which is an inexpensive, relatively quick, safe, and well-tolerated method of assessing the functional exercise capacity.[11]

Jaiyesimi and Fashakin (2007) reviewed that the reliability of PCI measurement under steady state, non-steady, and post-exercise condition was evaluated 30 participants (15 male, 15 female) and concluded that the PCI is easy to use, valid and reliable measure of energy expenditure. It also revealed a high test-retest reliability for non-steady state PCI, steady state PCI, and post-exercises PCI.[12] It is recommended as a useful tool for physiotherapist in the assessment and evaluation of functional performance.

IJzerman and Nene (2002) stated that PCI can be recommended as an outcome measure in clinical trials.[13] Basis of PCI is the relation that exists between HR and VO_2 in healthy participants up to submaximal workload. 54 adolescent and 40 adult were assessed in the gait laboratory using an infrared telemetry system. PCI of walking ranged from 0.15 b/m to 0.65 b/m in adolescent and from 0.2 b/m to 0.55 b/m in adults. There was no significant difference between median values of PCI in the two study groups. Adult males showed lower PCI than adult female.[14]

The PCI was founded on the principle that HR and walking speed are linearly related to VO_2 at the submaximal levels of exercise (Astrand and Rodahl). Therefore, the need of the study was to assess energy expenditure in normal individuals with different body mass index (BMI), during ground level walking by 6 MWT. This study was to establish mean PCI values of walking in normal individual.

The objectives of the study were to measure energy expenditure by the PCI during floor walking for different BMI and age and to compare energy expenditure by the PCI during floor walking for different BMI and age.

MATERIALS AND METHODS

It was a cross-sectional observational study, in which convenient sampling and total sample size was 115 which was calculated from the previous studies.

Inclusion criteria of the study were above 18 years of age group, both genders with normal healthy individual. Exclusion criteria of the study were musculoskeletal disorder, cardiovascular disorder, neurological disorder, metabolic disorder, and psychiatric disorders.

Study proposal was submitted and approved from the Institutional Ethical Committee. Participants were selected from karamsad and written informed consent was obtained after explaining study purpose and procedure.

Participants were asked to wear comfortable shoes and non-restrictive clothing. Participants were informed that before coming for the sessions, they should not have consumed any beverages such as tea, coffee, or any alcoholic substance. Before exercise testing, each participant's height (m) and weight (kg) were measured, and their BMI was calculated using the standard formula (kg/m^2). Each participant was given rest for 5 min and recorded resting HR. For measurement of the floor walking speed, participants were asked to walk on 30 meters straight floor track for 6 MWT at the normal speed.[15] During the walking test, the participant's HR was continuously measured by a pulse oximeter with a finger probe attached to the finger of participant. Rest was given to individual till HR returned to resting rate. The person could stop the test in between by informing us if the person was having any unusual feeling. Then, PCI was calculated using the following formula:

$$\text{PCI (b / min)} = \frac{\text{Walking heart rate (b / min)} - \text{Re sting heart rate (b / min)}}{\text{Walking Speed}}$$

RESULTS

In this study, 115 participants were taken. Among them, 59 were male and 56 were female. All the participants were able to complete 6 MWT at a comfortable speed. Data were analyzed using SPSS version 16.0 unpaired *t*-test and one-way ANNOVA was used to compare age, PCI, and BMI. For all the statistical test, significance level was fixed at 5%, i.e., the results were considered statistically significant when $P < 0.05$.

Table 1 shows that mean value of male age group was 40.86 and mean value of female age group was 40.66. Mean value of BMI of male and female was 25.39 ± 4.6 and 25.4 ± 4.56, respectively. Mean PCI of male was 0.27 ± 0.11 and 0.26 ± 0.10 was of female. The mean of the speed of walking in male was 82.69 ± 11.60 and that of female was 83.85 ± 13.63 in 6 MWT.

There is highly statistically significant relation with age and PCI ($P < 0.05$) as well as 18-50 year of age group. PCI is steady, whereas after 51-70 years of age group, PCI is increased (Table 2).

Table 3 depicts that relation of BMI and PCI was statistically significant ($P < 0.05$). Here, the underweight and normal BMI participants have PCI which was lower than the overweight and obese individual. While (Table 4) showing not much difference in distance covered by different BMI groups.

Table 1: Demographic data

Parameters	Male (mean±SD) *n*=59	Female (mean±SD) *n*=56
Age group	40.86±15.56	40.66±15.56
BMI	25.39±4.6	25.4±4.56
PCI	0.27±0.11	0.26±0.10
Speed	82.69±11.60	83.85±13.63
Distance covered	496.15±69.63	503.12±81.80

SD: Standard deviation, BMI: Body mass index, PCI: Physiological cost index

Table 2: Analysis of variance of age group and PCI

Source	SS	DF	MS	F	Prob>F
Between groups	0.27	4	0.068	6.45	0.0001
Within groups	1.16	110	0.010		
Total	1.43	114	0.012		

PCI: Physiological cost index

Table 3: Analysis of variance of BMI and PCI

Source	SS	DF	MS	F	Prob>F
Between group	0.13	3	0.045	3.90	0.0108
Within groups	1.29	111	0.011		
Total	1.43	114	0.012		

BMI: Body mass index, PCI: Physiological cost index

Table 4: Distances and BMI

BMI	Mean±SD	Frequency
Underweight	530.9±63.19	10
Normal	493.65±96.02	41
Overweight	506.04±63.15	48
Obese	475.56±48.98	16
Total	499.54±75.55	115

BMI: Body mass index, SD: Standard deviation

Adult age group is covering more distance than the middle age and older age (Table 5).

DISCUSSION

This study examined the relationship of age and BMI on energy expenditure in normal healthy individual of above 18 years male and female using 6 MWT. The study found that the PCI was steady in 18-50 years of age and increased in 51-71 years of age. The speed of walking was decreased as BMI increased. There is very less difference in the distance covered by different BMI groups of people.

Macgregor was suggested the PCI one of the cardiopulmonary factors, which combine the elements of HR and walking speed.[7] There was a study which concluded that significant correlation between PCI and oxygen uptake as they varied

Table 5: Distance and Age

Age group	Mean±SD	Frequency
18-30	519.86±69.48	37
31-40	515.75±99.80	20
41-50	491.04±90.46	23
51-60	476.77±44.70	18
61-70	471.88±42.60	17
Total	499.54±75.55	115

SD: Standard deviation

with walking speed which indicates a close relationship between cardiopulmonary factor and energy consumption while walking.[7] One of the previous studies concluded that PCI is an easy to use a valid and reliable measure of energy expenditure, and it is recommended as a useful tool for physiotherapist in the assessment and evaluation of functional performance.[10]

Table 2 shows that the relation of age group and PCI. In 18-50 years of age group, the mean value of PCI was 0.23 ± 0.08 and that of 51-70 years age group was 0.35 ± 0.11. The study concluded that the PCI was steady in 18-50 years of age and increased in 51-71 years of age. Similarly, the previous study had concluded that the younger age group walked significantly faster than the older age group. As a performance index, the test is therefore sensitive to age difference.[8,16,17] At slower speeds, the PCI values were high, indicating poor economy.[1] Table 5 projects the relation of age group and distance. In 18-30 years of age groups, mean and SD of distance was 519.86 ± 69.48. It gradually decreases as the age increase. Finally, in 61-70 years of age groups, mean and SD of distance was 471.88 ± 42.60. It concluded that distance covered by the individual was decline as the age increases.[18] As the age increases, walking speed of individual was decrease. Hence, PCI was increase and distance covered by individual was also reduced that required more energy expenditure.[19] Age-related declines in processing speed were hypothesized to underline the changes in cognition as well as a cerebellar pattern of gray matter and white matter variation was uniquely related to age-related declines in processing speed.[19]

Table 3 shows that the mean and SD value of underweight and normal was 0.23 ± 0.09 and 0.25 ± 0.09 and that of overweight and obese were 0.27 ± 0.12 and 0.35 ± 0.14, respectively. The speed of walking was decreased as BMI increased. Hence, it can be concluded that as BMI increases, the PCI increases which suggested poor economy. The energy expenditure was directly proportional to body weight. Sharma and Sarkar had concluded that in any physical activity, a large proportion of the energy was used to move the body weight and the metabolic cost was directly proportional to the body weight.[11] Table 4 concludes that there is very less difference in the distance covered by different BMI group of people. It is not necessary that underweight and normal BMI group of people cover more distance than overweight and obese group of people. The study done by Michaela Schimpl supports this study as a negative relationship between BMI and walking parameter distance is consistent with the findings of Levine.[18] As the difference in the resting HR and post immediate test HR increases, PCI increases. The previous study also supported this study.[11] There was one study support that short distance walking speed is associated with metabolic risk and subclinical atherosclerosis in older adult without overt cardiovascular disease.[20]

The result of the present study can be used as baseline subclinical diagnostic tool for cardiovascular diseases and fitness assessment of individual and physical fitness awareness. This study can be compared specifically based on different neurological conditions (e.g., cerebral palsy and stroke). It also can be done in different waling tracks (e.g., treadmill walking and floor walking, treadmill walking with inclination, and floor walking).[8] Here, assessment of the participants of the study was totally subjective and no screening tool was used to assess healthy individual which was limitation of study.

CONCLUSION

The present study concluded that as the age increases, the PCI increases, and as the BMI increases, the value of PCI increases, suggestive of more energy expenditure. The difference between resting HR and immediate post-test HR was directly proportional to PCI. The result of the present study can be used as baseline subclinical diagnostic tool and physical fitness awareness.

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