



Comparison of Physiological Cost Index during Treadmill Walking in Individuals having Different Body Mass Index

Author

Dr Namrata Parekh

B. N. Patel College of Physiotherapy, Anand, Gujarat, India

Email: parekhnamr@gmail.com

Abstract

India is facing dual burden of underweight and overweight. Approximately 43-48% of Indian men and women of 15-45 years of age group are facing the dual burden out of which 30-36% people are underweight and 9-13% people are overweight. PCI is founded on the principle that heart Rate & walking speed are linearly related to oxygen consumption at sub-maximal levels of exercise. A cross sectional observational study included 48 subject had willing to participate in the study. All subjects divided according to inclusion criteria. Then subjects were asked to performed treadmill walking at their natural walking speed. Then PCI was calculated according to formula. Level of significant was kept 5%. One-Way Anova test was apply and significance result was founded. Multiple comparisons between all groups was doing using Post hoc analysis in Bonferroni correction test. There was a significant difference in value of physiological cost index in different body mass index. There was relation between BMI and oxygen capacity.

Keywords: Physiological cost index, Body mass index, Modified Borg Scale, Treadmill walking, Heart rate.

Introduction

The physiological cost index (PCI) is a simple tool used to measure energy expenditure during walking. The PCI was established by MacGregor who recognized the need for a simple, functional & non invasive method of measuring the physiological cost of walking that could be applied in clinical environments. The PCI is founded on the principle that heart rate & walking speed are linearly related to oxygen consumption at sub-maximal levels of exercise.^[1,2]

Energy expenditure is traditionally calculated by measuring oxygen consumption which require to collect expired gases, but this methods involves

the use of expensive and cumbersome equipment which is unavailable in the clinical environment.^[3]

The PCI offers a practical alternative. It is an empirical index and defined by MacGregor as follows:

PCI (beats/meter)^[1] = Walking heart rate—resting heart Rate (beats/min) walking speed (m/min)

The PCI, an index of walking of efficiency, has been investigated for reliability and validity. The PCI has reliability ($r=0.843-0.944$)^[4] and validity ($r=0.86$).^[5] The PCI is closely correlated with METs ($r=0.88$) suggests that this index can be useful in energy expenditure.^[6]

The criteria for the PCI are that

1. The subject walks at their ‘ natural ‘ walking speed where energy efficiency is optimal.^[1]
2. True resting heart rate is obtained.^[2]
3. Walking heart rate is measured at steady state or non-steady state or as post exercise heart rate.^[2,3]

Astrand and Rodahl (1986) have shown that the linear relationship between heart rate and oxygen consumption is fundamental to the PCI and Rose et al. (1991) have shown when calculating PCI the resting heart rate is sensitive and must be measured with accuracy.^[3] In our study also included very accuracy measured resting heart rate.

According to the WHO estimates, the undernourished population in the world has declined and is roughly around 1.2 billion, whereas the over nourished population has increased to 1.2 billion.^[7]

WHO data also show that, globally, there are more than 1 billion adults overweight and 300 million obese people. The problem of obesity is increasing in the developing world with more than 115 million people suffering from obesity related problems.^[8]

India is facing dual burden of underweight and overweight. Approximately 43-48% of Indian men and women of 15-45 years of age group are facing the dual burden out of which 30-36% people are underweight and 9-13% people are overweight.^[9]

Underweight due to under-nourishment is most common problem in developing countries and it is burning issue in our country.^[10,11] Though underweight is commonly seen in rural areas, it is not uncommon in urban areas. Obesity has reached epidemic proportions in India in the 21st century, affecting 5% of the country's population.^[12] Urbanization and modernization has been associated with obesity.^[13]

The prevalence of overweight and obesity in urban population of Jamnagar was found to be 22.04% and 5.20%, respectively.^[14]

Hippocrates (b. 460-377 BC), the ancient Greek physician regarded as the Father of Medicine, taught that obesity is a health risk and considered it a cause of disease that lead to death. “Obesity refers to the over fat condition that accompanies a constellation of co-morbidities that includes one or all of the components of the obese syndrome.”

Obese syndrome includes glucose intolerance, insulin resistance, dyslipidemia, Type 2 diabetes, hypertension, elevated plasma leptin concentration, increased visceral adipose tissue, and increased risk of coronary heart disease and cancer.^[15] Complication with the heart is one of the more commonly highlighted secondary effects of obesity. In obese individuals, atherosclerosis, which is a hardening of the arteries, is ten times more present than in individuals who are not obese. This can lead to coronary artery disease, which is another prevalent health effect associated with obesity.^[16] The Body Mass Index (BMI) is an index of weight to height (kg/m²) and is considered to be the most useful indicator of health risks associated with both overweight and underweight.^[17,18]

The international classification of adult BMI according to WHO^[19].

CLASSIFICATION	BMI(Kg/m ²)
UNDERWEIGHT	<18.5
NORMAL	18.50-24.99
OVERWEIGHT	≥25.00
OBESE	≥30.00
OBESE CLASS I	30.00-34.99
OBESE CLASS II	35.00-39.99
OBESE CLASS III	≥ 40.00

Classification of BMI according to revised Indian Guideline^[20]

CLASSIFICATION	BMI(kg/m ²)
UNDERWEIGHT	<18.5
NORMAL	18.50-22.9
OVERWEIGHT	23.0-24.9
OBESE	≥25.0

Perception of effort also known as perceived exertion or sense of effort refers to the conscious sensation of how hard, heavy and strenuous a physical task is. This perception depends mainly on feeling of effort in the active limbs and

sensation of heavy breathing. Perceived exertion accurately reflects relative exercise intensity, which depends on two factors; absolute work load and individual's exercise capacity.^[21]

Sharma, H et al(2016),” in the study Correlation between six Minute walk test and physiological cost index in healthy Indian females.” suggested that increase in heart rate after exercise was positively correlated with increase PCI value. They also suggested that increase BMI value was positively correlated with increase PCI value. In any physical activity, a large proportion of the energy was used to move the body weight and the metabolic cost was directly related to body weight.^[22]

The aim of the study is to measure energy expenditure during treadmill walking, effect of BMI on energy expenditure and thus, to compare physiological cost index during treadmill Walking in Underweight, Normal, Overweight & Obese individuals.

Methods

48 subjects 20-40 years between both gender who had given written informed consent form were included in the study by purposive sampling technique. Those who have any cardiovascular, vestibular, muscular skeletal, and neurological disease were excluded in the study. A cross sectional study included 48 subjects BMI were calculated, and then accordingly were distributed to the respected groups. i.e, Group 1. Underweight individuals. Group 2. Normal individuals . Group 3. Overweight individuals. Group 4. Obese individuals. Before starting procedure explain modified borg scale and natural walking speed. Explain subjects that they perform walking and not running. Subject 's resting heart rate & Modified Borg scale (rating of perceived exertion) were taken to access hemodynamic stability. Resting heart rate were noted by pulse oximetry. To measure resting heart rate subjects rest in a chair for 5 min for stabilization of the heart rate. Resting heart rate were recorded by taking every 10 second heart rate for 2 min during initial

resting period & average heart rate were taken^[24] Then subjects were asked to perform treadmill walking at their natural walking speed.^[25] Subjects began the walking speed were 2 km/h. After they started walking they increased speed and corresponding to a perceived exertion level. After they decide their own natural walking speed, they maintain the speed up to they feel exertion level 5 i.e., severe. subjects were asked to stop the walking if they feel exertion level 5 i.e. “severe” according to modified Borg scale.^[23,26] Walking heart rate was noted by pulse oximetry. Then after, walking heart rate was calculated as the average heart rate recorded at 10 second interval for the last 30 seconds during walking ^[24] Also speed of walking & time taken to reach exertion level of 5 were noted. Then PCI was calculated according to following formula.

**PCI (beats/meter) = Walking heart rate—
resting heart Rate (beats/min)/ walking speed
(m/min) [1]**

Same procedure was repeated for Group 2, group 3 & group 4 value of PCI was calculated.

Statistical Analysis

The result was analyzed using SPSS version 16.0. The level of significance was kept at $p < 0.05$. The data was screened for normal distribution using Kolmogorov Smirnov normality test and Shapiro-wilk test. Data was normally distributed. Intergroup comparison of physiological cost index in all four group was doing using parametric One - Way Anova test. Multiple comparisons between all four groups was doing using Post hoc analysis in Bonferroni correction test.

Result

48 subjects were included in the study. In Underweight 16.7% male and 83.3% female were participated in study. They mean age were 22. In Normal 33.3% male and 66.7% female were participated in study. They mean age were 22. In Overweight 33.3% male and 66.7% female were participated in study. They mean age were 24. In

Obese 16.7% male and 83.3% female were participated in study. They mean age were 25. Show in table 1 and 2.

Table: 1 Gender Distribution of Individuals.

Group	Male	Female
1 (Underweight)	16.7%	83.3%
2 (Normal)	33.3%	66.7%
3 (Overweight)	33.3%	66.7%
4 (Obese)	16.7%	83.3%

Gender distribution in four group according to percentiles.

Table: 2 Age Distribution of Individuals

GROUP	MEAN AGE \pm SD
Underweight	22.91 \pm 1.67
Normal	22.41 \pm 4.51
Overweight	24.41 \pm 3.80
Obese	25.33 \pm 4.51

Mean age distribution in four group.

Table: 3 Comparison of Physiological cost Index between four Groups. ONE –WAY ANOVA

GROUP	MEAN \pm SD (beats/meter)	f VALUE	p VALUE	SIGNIFICANCE
1(Underweight)	0.60 \pm 0.04	57.01	0.001	YES
2 (Normal)	0.68 \pm 0.06			
3 (Overweight)	0.85 \pm 0.06			
4 (Obese)	0.92 \pm 0.08			

Comparison of Physiological Cost Index in Under weight, Normal, Overweight, and Obese individuals. Intergroup comparison is shown Table 3. One-Way Anova test was applied.

In study, the mean value of PCI for Underweight was 0.60 beats/meter, Normal was 0.68 beats/meter, Overweight was 0.85 beats/meter, and Obese was 0.92 beats/meter.

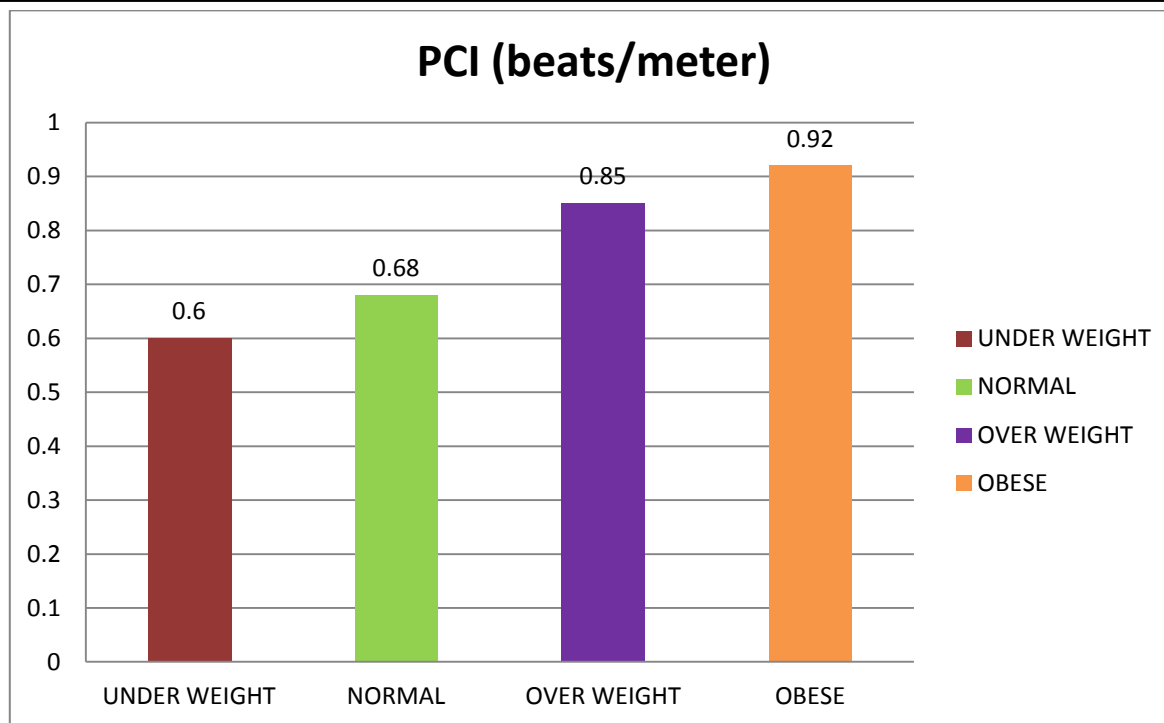
There is statistical significant difference in value of physiological cost index between (Underweight and Normal), (Normal and Overweight), (Obese and Underweight), (Obese and Normal), and (Overweight and Underweight) individuals during treadmill walking. There is statistical no significant difference in value physiological cost index between (Overweight and Obese).

PCI value was founded, in this study highest in obese than overweight and normal. Lowest PCI value was founded in underweight individuals.

In Table 4 is shown Post hoc analysis was done using Bonferroni correction for multiple comparisons between the groups. Graph 1 shown also comparisons between all the groups.

Table: 4 POST-HOC multiple comparison of mean difference in Physiological Cost Index between the groups.

GROUP COMPARISON	MEAN \pm SE	P VALUE	SIGNIFICANCE
1 vs 2 (Underweight/ Normal)	0.08 \pm 0.02	0.031	YES
2 vs 3 (Normal/ Overweight)	0.17 \pm 0.02	0.001	YES
3 vs 4 (Overweight/Obese)	0.07 \pm 0.02	0.104	NO
4 vs 1 (Obese/Underweight)	0.32 \pm 0.02	0.001	YES
2 vs 4 (Normal /Obese)	0.24 \pm 0.02	0.001	YES
3 vs 1 (Overweight/Underweight)	0.25 \pm 0.02	0.001	YES



Graph 1: Comparison of Physiological Cost Index between Four Groups

Discussion

This study was conducted to compare the value of physiological cost index in Underweight, Normal, Overweight, and Obese individuals during treadmill walking. This was done by calculating the physiological cost index in different four groups.

The result of this study suggested there is a significant difference in the value of the Physiological Cost Index between (Underweight and Normal), (Normal and Overweight), (Obese and Underweight), (Obese and Normal), and (Overweight and Underweight) individuals. There are several changes that occur due to an increase in body mass index, which may affect heart rate and walking speed in individuals, which is responsible for this result.

The hypothesis behind the highest PCI value found in obese is that obese individuals walk slower than normal, and the most important reason was that during treadmill walking, heart rate is increased because of altered cardio-respiratory changes in obese and overweight.

In the respiratory system, there is a decrease in chest wall compliance associated with the obese individuals' accumulation of fat in and around the ribs, diaphragm, and the abdomen. Although

considerable energy may be spent in overcoming the reduction in chest wall compliance, it accounts for only one-third of the increased work of breathing, with the remaining energy increase in non-elastic work or an inefficiency of the respiratory muscles. Non-elastic work is air flow limitation and airway resistance. Increased work of breathing and increased resistance stimulate breathlessness due to an increased heart rate. Obese individuals undergo cardiac changes, including an increase in stroke volume, cardiac output, left ventricular end-diastolic pressure, and pulmonary artery pressure. The hypervolemic and hyperdynamic states increase left ventricle work and lead to an increase in cardiac mass. The increase in heart mass is predominantly due to an increase in muscle mass of the left ventricle and not due to epicardial or myocardial fat infiltration.^[27]

Some studies have found similar results that the physiological cost of walking was higher in obese boys than non-obese boys. The difference was found because the maximum heart rate (HR max) is higher in obese boys.^[28]

Raymond C et al. suggested that obese adults may prefer to walk slower than normal individuals. The mean net metabolic rate and oxygen consumption

was 11% higher for the obese subjects compared with normal weight subjects. Greater body mass and heavier legs increase in net energy expenditure of 15% (per total kilograms). The mean net metabolic rate was 11% higher for the obese subjects compared with normal weight subjects. The greater difference in metabolic rate because, in of the greater adiposity (percent fat) of their subjects. The metabolic rate increase with increase BMI. Obese subjects was 36 kg heavier than the normal weight subjects.^[33]

Some studies, found in similar results that with slower speeds, the PCI values were high, indicating poor economy. The PCI values decreased to maximum economy as walking speeds increased. And they found PCI values relationship with body weight, gender, walking speed, and leg length.^[29]

NHANES (National Health and Nutrition Examination Survey) suggested Obesity is associated with high insulin and leptin levels. High levels of insulin and leptin increase sympathetic nervous system activity and engender increased chronotropy, vasoconstriction, pulse rate and blood pressure.^[30]

American Heart Association, suggested that obesity was develop imbalance between energy intake and energy expenditure. Energy expended in physical activity. This varies due to differences in body mass.^[31]

Study suggested that increase energy expenditure by increasing physical activity, In obesity increase sympathetic nervous system activation lead to increase heart rate and energy expenditure.^[32]

Increased body mass with increased energy expenditure. In weight bearing exercise like (walking, running) also increased energy expenditure. In obese high energy expenditure, because of extra energy required to lift heavier lower limbs. Heart rate and oxygen consumption are linearly related, so increase heart rate leads to increase energy expenditure.^[15]

Recently a study 2016, suggested that increase in heart rate after exercise was positively correlated with increase PCI value. They also suggested that

increase BMI value was positively correlated with increase PCI value. They concluded any physical activity, a large proportion of the energy was used to move the body weight and the metabolic cost was directly related to body weight. They also suggested that no correlation in VO₂max and PCI. They suggested that PCI value directly associated with weight and BMI.^[22]

Conclusion

There is statistical significant difference in value of physiological cost index between all group individuals, excepted overweight and obese. The value of physiological cost index is higher in obese and overweight than normal. Lowest Physiological cost index value was found in underweight individuals during treadmill walking.

Conflicts of interest: None

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