

Reliability and Reproducibility of Physiological Cost Index (PCI) as an Energy Expenditure Index among Asian Individuals

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Abstract

Introduction: Physical activity and energy expenditure are important markers of wellbeing. Energy expenditure index can be assessed by bicycle ergometer and treadmill test but they are costly and are not suitable for physically challenged ones. Hence, simpler and straightforward tests like Physiological Cost Index can be useful in a broader perspective. However, it is not known whether they are reliable and reproducible in Asian population.

Methods: A total of 10 young randomly selected healthy individuals performed 50m, 100m and 150m walking test at their self-selected preferred speed. The test was repeated three times on each distance. The resting measurements were taken and their Physiological Cost Index during exercise was calculated using MacGregor's equation.

Results: The mean age was 24.8 years (22-39 years). The mean speed of walking was 65m/min. The mean body mass index was 20.68. Their mean PCI values for 50, 100 and 150m distance walks at self-selected, preferred speed did not show statistically significant difference from each other. On a reproducibility test, irrespective of the distance walked, the first test (Test I) had statistically significant higher PCI values than Test II and Test III ($p < 0.05$) for the respective distance walked.

Conclusion: Physiological Cost Index can be estimated using MacGregor's equation with walking varying distances (50m, 100m and 150m) at a self-selected and preferred speed. The first test tends to overestimate PCI as compared to the second and third tests on the same distance. However, the second and third tests (trials) seem consistent.

Keywords: Exercise, Energy Expenditure Index, Physiological Cost Index

Introduction

Physical exercise like walking is dependent on energy expenditure because any movement of the body requires muscular energy^{1,2}. The usual physiological parameters for measurement of energy expenditure during walking are heart rate, oxygen uptake and respiratory quotient.^{3,4} The respiratory methods for estimating energy consumption are not acceptable to handicapped children because these procedures necessitate the use of nose clips and mouth⁵ - pieces and also a collecting device, such as a Douglas bag, carried on the body.³ This interferes with performance by causing psychological distress to a child already encumbered with an orthosis and possibly a walking aid.^{3,5} The instrumentation required for respiratory methods is also not available in most clinical settings. A more acceptable method of estimating energy consumption is to monitor the heart rate response to activity.⁶ Heart rate is more easily measured than oxygen uptake and has been shown in adults to be an accurate

and convenient estimate of energy expenditure.^{7,8} In able-bodied subjects heart rate and oxygen uptake have a linear relation upto submaximal work loads.^{9-11,10} This has enabled clinicians and rehabilitation engineers to monitor the energy cost of a variety of physical activities by monitoring heart rate alone. The linear relationship between heart rate and oxygen consumption throughout a wide range of walking speeds for both normal children¹² and children with cerebral palsy⁷ substantiates the use of heart rate as a measure of energy consumption for children while walking.⁷

Energy expenditure index based on heart rate and walking speed has been termed Physiological Cost Index (PCI) by MacGregor.^{13,14} PCI is the ratio of heart rate per meter walked. PCI has been found to be a simple, useful clinical tool for assessing efficiency of walking. However, not many studies have been done to evaluate the reproducibility and reliability of PCI without using cumbersome electronic gadgets and telemetry. Estimation

of PCI was preferred to measurement of heart rate alone because it takes into account the speed of locomotion and thereby indicates the energy cost of locomotion^{15,16}; in other words, the efficiency of locomotion.¹⁰ The present study is designed to estimate PCI in order to validate its reproducibility and reliability among normal Asian individuals during walking by simply measuring pulse rate and determining walking speed without recourse to sophisticated instruments.

Methods

10 young healthy normal adults of ages between 18 to 45 years were recruited for the study. They were mostly students from the Department of Physiology, Shiridi Sai Baba Cancer Hospital and College of Nursing, Manipal. With preliminary screening, they were excluded if they had fever, physical disability, cardiac or pulmonary disease, using medications and had history of recent surgery. The study was conducted at the Locomotor Evaluation and Gait Analysis Laboratory (LEG Lab) of the Department of Orthopaedics in Kasturba Medical College and Hospital, Manipal during the period between January 2000 to December 2000.

The LEG Lab which was controlled for humidity, temperature and illumination as well as continuously air-conditioned had a marked rectangular walkway of 16.66 meters on the floor. A dedicated programmed computer was used to assist in the timing of the subject's walk. The computer was programmed to calculate PCI when resting heart rate, final heart rate, distance walked and the time taken for walking were fed.

Experimental Protocol

After the initial briefing about the study and written informed consent, the subjects were screened for inclusion and exclusion criteria. Then the subjects were made to walk distances of 50, 100 and 150 m at self-selected, preferred speed and their PCI values were obtained and analyzed to see how PCI varied with different distances walked. In the next session, the subjects were asked to perform the 50, 100 and 150m walks at their self-selected preferred speed on three different occasions. All the experiments were conducted at the same time of the day (10:30 am - 12:30 pm) to minimize the time of the day variability. The data was analyzed to assess the reproducibility of estimates of PCI.

Radial pulse was measured for 15 secs only instead of 30 secs or 1 min, because within 30 to 45 secs of completion of a specified walking test, pulse rate came back to normal resting rate and no difference in heart rate could be appreciated.¹⁷ Radial pulse in the first 15 secs would reflect the actual change in heart rate brought about by walking.

Calculation of Physiological Cost Index using MacGregor's equation

Energy expenditure index based on heart rate and walking speed has been termed Physiological Cost Index (PCI) by MacGregor.¹³ PCI is the ratio of heart rate per meter walked and it is calculated by the following formula:

$$\text{PCI} = \frac{\text{Walking heart rate (beats/min)} - \text{Resting heart rate (beats/min)}}{\text{Speed of walking (meters/min)}}$$

The PCI is expressed as beats/meter.

The data obtained are expressed as mean \pm standard deviation (SD) and were analysed using standard statistical package (SPSS). The data was subjected to paired 't' tests (Student 't' test) PCI variation with different distances at self-selected preferred speed, to check the reproducibility of PCI as a measure of energy consumption during walking at self-selected preferred speed, and to see the correlation of PCI with slow speed and fast speed 100m walks.

Results

Effect of Distance on Physiological Cost Index

A total of 10 young and healthy individuals performed 50m, 100m and 150m distance at their self-selected preferred speed walking test. Their mean PCI values have been presented in the Table 1 as Mean \pm SD.

Table 1. The effect of varying distances on PCI at the self-selected preferred speed.

Distance walked	No. of subjects	PCI \pm S.D.
50m	10	0.28 \pm 0.15
100m	10	0.25 \pm 0.09
150m	10	0.27 \pm 0.11

Table 2. The comparison of mean PCI with varying distances at the self-selected preferred speed

Mean \pm S.D.	Mean \pm S.D.	Differences (Mean \pm S.D.)	Paired 't'	p-Value
PCI (50m) 0.28 \pm 0.15	PCI (100m) 0.25 \pm 0.09	0.03 \pm 0.14	0.75	0.47
PCI (50m) 0.28 \pm 0.15	PCI (150m) 0.27 \pm 0.11	0.02 \pm 0.12	0.41	0.69
PCI (100m) 0.25 \pm 0.09	PCI (150m) 0.27 \pm 0.11	-0.02 \pm 0.11	- 0.50	0.63

Note: The numbers within brackets after PCI indicate the distance walked.

In Table 2, mean PCI values for 50, 100 and 150m distance walks at self-selected, preferred speed were compared with each other and it was observed that there was no statistically significant difference between PCI values for varying distances of 50, 100 and 150 meters. Among the 10 subjects, 8 were males and 2 females. The mean age was 24.8 years (range 22-39 years). The mean speed of walking was 65m/min. The mean body mass index (BMI) was 20.68.

Reproducibility of Estimation of PCI

Comparison of reproducibility of measurement of PCI values when estimated with varying distances of test walk.

Table 3. The comparison of reproducibility of measurement of PCI over varying distances

Distance Walked	No. of Subjects	Mean PCI Values		
		Test I	Test II	Test III
50m	10	0.20 ± 0.05*	0.16 ± 0.05	0.17 ± 0.03
100m	10	0.24 ± 0.07*	0.16 ± 0.04*	0.18 ± 0.05
150m	10	0.22 ± 0.07*	0.20 ± 0.05	0.19 ± 0.05*

Note: * Values which were significantly different from other PCI readings for the same distance walked.

It was observed that, irrespective of the distance walked, the first test (Test I) had a higher PCI value than Test II and Test III for the respective distance walked. These differences were statistically significant ($p < 0.05$).

Discussion

The major findings of the study is the physiological cost index as assessed by using MacGregor's equation over varying distances (50m, 100m and 150m) with walking at a self-selected and preferred speed among young adults of Asian origin. On three trial attempt (Test I, Test II, Test III) on the reproducibility of the test, irrespective of the distance walked, the first test (Test I) had a statistically significant higher PCI values than Test II and Test III ($p < 0.05$) for the respective distance walked.

Here, we showed that PCI did not differ significantly with varying distances of 50, 100 and 150m (Table 2) when the subjects walked at their self-selected preferred speed in one session.^{13,14,18} The mean PCI value for 50m walk was 0.28 ± 0.15 beats/m, for 100m walk 0.25 ± 0.09 beats/m and for 150m walk 0.27 ± 0.11 beats/m (Table 1). The participants in this study were 8 males and 2 females with ages ranging from 22 to 39 years and mean BMI (body mass index) of 21. Table 1 also indicated that the mean PCI value of the subjects for 50m distance walk at preferred speed demonstrated a larger

standard deviation (0.28 ± 0.15) than the mean PCI value for 100m (0.25 ± 0.09) and 150m distance walk (0.27 ± 0.11). In contrast to one outlying PCI value of 0.67 for 50m walk, all the PCI values for 100 and 150m walk fell within the MacGregor's normal range (0.11 - 0.51 beats/m).¹³ This finding probably supports the view that anxiety and apprehension about the investigation exerted its maximum effect during most of the 50m walking tests to which the subjects were exposed for the first time.¹⁹ It could be presumed that the subjects got more accustomed during the subsequent tests in the same session.⁶

Table 2 results demonstrated that there was no statistically significant difference in the PCI values for 50, 100 and 150m distance walks at self-selected preferred speed. The reason for selecting these 3 specific distances was that MacGregor had used a 200m figure-of-eight walk path on the floor of his laboratory to obtain the normal PCI range.¹³ Since MacGregor's index was our major reference and our laboratory had a marked rectangular walk way 16.66m in perimeter, 50,100 and 150m distances were chosen as walking test distances. 200m distance was not considered because the small size of the walkway would necessitate 12 rounds at a stretch.²⁰ This could be monotonous and uncomfortable for the subjects. The 50 and 100m distance walks would be convenient for PCI estimation in disabled children^{11,21}, and 100 and 150m distance walks would be appropriate for older children and more 'physically fit' individuals.¹²

Next part of the study was aimed at assessing the reproducibility of PCI estimation as a measure of energy consumption during walking. One interesting trend noticed from the analysis was that more than 50% of the PCI values obtained during Test I were significantly higher ($p < 0.05$) than the PCI values obtained during the subsequent two tests. It appeared that the 'first time exposure' factor came into operation to produce greater change in heart rates of the subjects.²² It is presumed that stress of a new investigative test and unfamiliar surroundings stimulated the sympathetic nervous system more during the 1st session than during the subsequent sessions.²³

Hence, this study, therefore, proved as a guide for further investigations to reinforce or refute the findings. The reproducibility aspect and non-variance of PCI values with different distances of walk at preferred speed were indicated by the results of this study. However, the study pointed out the need to investigate further the difference between PCI values during Test I and PCI values during Test II and III.

Conclusion

The present study employed a simple clinical method to evaluate Physiological Cost Index (PCI) as a measure of energy consumption during walking in a cohort of healthy young adults. The PCI assessed by using MacGregor's equation over varying distances (50m, 100m and 150m) with walking at a self-selected and

preferred speed is consistent irrespective of the distances subjects was made to walk. The first test estimates of PCI demonstrated statistically significant higher values as compared to second and third tests on the same distance but second and third seem consistent. Therefore, the reproducibility of second and third recordings of PCI was excellent. In conclusion, this test can be employed to estimate PCI among young adults after subjects are taught and rehearsed.

Conflict of interest: None declared

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