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A Comparative Study of Physiological Cost Index in Forward Treadmill Walking Versus Retro Treadmill Walking in Obese Class 1 Individuals

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ABSTRACT

Background: Retro (backward) walking has been shown to enhance cardiovascular endurance and musculoskeletal fitness. The treadmill is a commonly used and easily accessible tool for physical fitness training. Previous research supports the positive effects of backward walking on muscle activation. However, no study to date has compared the physiological cost index (PCI) between forward and backward treadmill walking in Class I obese individuals.

Study design: Cross sectional study

Objective: To compare the physiological cost index during forward and backward treadmill walking in Class I obese young adults.

Materials and Methodology: A total of 108 young adults (both male and female) with a body mass index (BMI) between 25 and 29.9 kg/m² participated voluntarily. Participants were randomly assigned to two groups: 55 individuals performed forward treadmill walking, and 53 performed backward treadmill walking at their self-selected comfortable walking speed. Resting heart rate and walking heart rate were recorded before and after treadmill activity. PCI was calculated using MacGregor's formula:

PCI = (Walking HR - Resting HR) / Walking Speed

Results: A significant difference in PCI was observed between the two groups.

- Backward walking group: Mean PCI = 0.7364
- Forward walking group: Mean PCI = 0.5865
- P-value: 0.0049

This indicates that energy expenditure was significantly greater during backward treadmill walking compared to forward walking.

Conclusion: Backward treadmill walking results in a significantly higher physiological cost index than forward walking in young adults with Class I obesity. This suggests increased energy demand and potential benefits for weight management and cardiovascular conditioning through retro walking.

Keywords: Physiology cost index, Retro walking, Forward walking, BMI.

INTRODUCTION

The Physiological Cost Index (PCI) is a simple tool used to measure energy expenditure during walking.

The PCI was introduced by MacGregor who developed a simple, functional and non-invasive method of measuring the physiological cost of walking that could be equally applied in clinical environment. The method for estimating the energy cost using measurement of Heart rate(HR) is PCI. The PCI was calculated from the difference in walking Heart Rate(HR) and resting HR divided by the walking speed. [1]

PCI (beats/m) = walking heart rate - resting rate (beats/min)/walking speed (m/min)

The PCI value reflected the increase in HR required for walking and is expressed as a heartbeat per meter. These method was administered in clinical situation which is easily accessible, cost effective and feasible. PCI is one of the good indicators of energy cost. 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. 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).[1]

Walking is humans most basic motion and has been used for health improvement for decades. Walking exercise has diverse effects so that feet are also called the second heart. Walking may enhance cardiovascular endurance as well as developing leg muscles. Walking is popular, convenient, and relatively safe form of exercise and also hold great promise for weight management. Walking exercise has low risk of injuries and therefore it is recommended for elderly people, the weak, those who did not do activities for a long time and those with chronic pain.[3]

Backward locomotion is the act of walking in reverse, so that one travels in the direction of one's back rather that facing front. It is defined as Retro movement, the reverse of the normal movement. [4] The gait characteristics of Retro walking when compared with Forward walking differ greatly (Grasso et al.; 1998). Initiation with toe strike is the hallmark of Retro walking. The stance of Forward walking begins with heel strike and ends with toe-off whereas in case of Retro walking, the toes are the first ones to contact the ground and heel is lifted off the ground at the end of the stance phase.[5]

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".[7] Obesity, which broadly refers to excess body fat, has become an important public health problem. Prevalence of obesity is increasing day by day. [8]

The Body Mass Index (BMI) is an index of weight to height (kg/m^2) and is considered to be the most useful indicator of health risks associated with both overweight and underweight.[10]

Forward and backward treadmill walking are simple and natural forms of exercise that can be performed easily by most individuals. Obesity, a major contributor to global mortality, continues to rise at an alarming rate. Walking is one of the most accessible and effective exercises for managing and reducing obesity. Therefore, it is important to determine which type of walking—forward or backward—results in greater energy expenditure and provides more significant benefits for individuals with obesity.

MATERIALS AND METHOD

A total of 108 individuals classified as Class I obese (BMI between 25 and 29.9 kg/m^2) were recruited for this study using a convenient sampling method. Participants with known cardiovascular, pulmonary, neurological, or musculoskeletal disorders that could interfere with treadmill walking were excluded. Ethical clearance was obtained from the Institutional Ethics Committee of Uka Tarsadia University, and written informed consent was secured from all participants prior to data collection.

Initial assessments included demographic data, resting heart rate, and the Physical Activity Readiness Questionnaire (PAR-Q). Participants were then randomly allocated into two groups: Group A performed forward treadmill walking, while Group B engaged in backward treadmill walking. Each participant walked until a steady heart rate was achieved. Walking speed was measured in meters per minute, and the heart rate during activity was recorded over 15 seconds and converted to beats per minute.

The data were then used to calculate the Physiological Cost Index (PCI) using MacGregor's formula:

PCI = (Walking Heart Rate – Resting Heart Rate) / Walking Speed

All collected data were statistically analyzed to compare the PCI between forward and backward treadmill walking, thereby assessing the relative energy expenditure of each walking modality.

RESULT:

The analysis was performed using SPSS version 20.0, maintaining a significance level of $p < 0.05$. A comparison between the physiological cost index of forward walking and retro walking was conducted using an independent t-test. A total of 108 participants were enrolled in the study.

	No. of subjects	Age	Height (in m)	Weight (in kg)	BMI	Resting heart rate
FORWARD WALKING	55	22.8±0.716	1.66±0.013	76.51±1.26	27.39± 0.19	91.38±1.27
RETRO WALKING	53	21.17±0.71	1.67±0.016	76.60±1.70	27.17±0.209	91.49±1.42

Table 1: The mean value of physical characteristics of subjects participated in the forward and retro treadmill walking.

The mean speed and Physiological cost index of subjects are shown in Table 2. The mean value of PCI for Retro walking was 0.736402 and for Forward walking 0.586522. There is statistical significant difference in physiological cost index in Forward and Retro walking i.e. p value < 0.05.

	Speed	PCI
FORWARD WALKING	4.23818 ± 0.10729	0.586522 ± 0.026967
RETRO WALKING	3.29245 ± 0.10729	0.736402 ± 0.031689

Table 2: The table shows the average PCI and speed of forward and retro treadmill walking

DISCUSSION

The Physiological Cost Index (PCI), developed by MacGregor in 1979, was introduced as a simple, functional, and non-invasive method to assess the physiological cost of walking, particularly suitable for clinical use. It is based on the principle that at submaximal levels of exercise, heart rate and walking

speed are linearly related to oxygen consumption (VO_2).

The primary objective of this study was to compare the PCI during forward and backward treadmill walking in individuals classified as Class I obese.

In the current study, the mean PCI was notably higher in the retro walking group compared to the forward walking group. This suggests that retro walking demands greater energy expenditure than forward walking. Interestingly, despite the lower average walking speed during backward walking, the energy expenditure was still higher, indicating that retro walking is more physiologically demanding.

Supporting evidence from Kenji Masumoto et al. highlights increased muscle activity in key muscle groups—including the paraspinal muscles, vastus medialis, and tibialis anterior—during backward walking. Increased muscle recruitment likely contributes to the higher energy cost observed during retro walking [20].

Troy L. Hooper et al. also reported elevated cardiorespiratory responses during both forward and backward treadmill walking. They proposed that retro walking requires the recruitment of a larger number of motor units, leading to increased metabolic demand. Additionally, they noted that stride length and frequency differ between the two walking modes. The shorter stride length observed in retro walking increases oxygen consumption due to biomechanical inefficiency, aligned with the muscle's length-tension relationship [15].

In another study, Ashwini Dangi et al. found that backward walking elicits higher cardiovascular demand due to the altered role of the quadriceps, which acts as a decelerator in forward walking but becomes an accelerator in backward walking. This change in muscle function leads to increased oxygen uptake, making retro walking a viable exercise for improving cardiorespiratory fitness and promoting weight reduction [14].

CONCLUSION

Statistical analysis revealed a significant difference in the Physiological Cost Index (PCI) between retro walking and forward walking among individuals with Class I obesity. Retro walking demonstrated a higher PCI, indicating greater energy expenditure compared to forward walking. Furthermore, the average walking speed was lower during retro walking, suggesting that even at a reduced pace, retro walking requires more energy. This increased energy demand highlights the potential of retro walking as an effective exercise strategy for individuals with Class I obesity.

Limitation of the study

- The sample size was limited.
- Gender stratification was not conducted in the study.
- Only individuals classified as Class 1 obese were included in the study.

Future Recommendation

The findings of this study indicate that backward walking is more effective than forward walking, as it results in a higher physiological cost index (PCI), signifying greater energy expenditure compared to forward walking. We recommend that participants consider incorporating backward walking into their exercise routine. Engaging in backward walking can aid in weight reduction by enhancing cardiovascular endurance and promoting muscle activation, thereby contributing to a decrease in overall body composition.

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