METABOLIC CHARACTERISTICS WHEN WALKING IN NEGATIVE HEEL SHOES

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INTRODUCTION

One type of negative heel shoe, named 'slimming shoes' recently designed by a shoe maker in Hong Kong, is characterized by having the heel part of the sole lower than the toe part. The sole was designed so that there is an elevation in the area of forefoot and the shoe itself tilts the foot into about 10 degrees of dorsiflexion. The designer of the slimming shoes believed that walking with the sliming shoes mimics up-hill walking which could increase energy expenditure, improve cardiorespiratory function, and subsequently slim the body. The biomechanical and metabolic responses to human locomotion related to footwear have been reported by a number of the studies. However, most of these studies are related to the metabolic cost with high-heeled shoes. Studies about the effects of negative shoes on metabolism are a few. Mann et al. (1976) studied the biomechanics of earth shoes (negative shoes) and compared the gait pattern and electromyography (EMG) activity of the lower extremities when walking in bare feet, tennis shoes, and in earth shoes. The authors were not able to measure any changes in the gait patterns of subjects walking in bare feet, tennis shoes, or earth shoes. Their study showed that the metabolic cost during walking was not influenced by the type of the shoes wore. However, studies of walking in high-heeled shoes have found that the height of shoes heel can influence the energy expenditure (Ebbeling et al., 1994). Therefore the question that arises is whether walking in negative shoes can influence the metabolism and enhance cardiorespiratory activity? The purpose of this study was to examine whether there is any changes in metabolism, in terms of oxygen uptake, heart rate, breathing frequency, and energy expenditure when walking in negative shoes compared with walking in regular shoes.

METHODS

Subjects and shoes A group of six healthy subjects participated in this study. None of the subjects were experienced in walking in negative shoes. Their individual characteristics are given in Table 1. All subjects were fully informed about the purpose and the procedures of the study and gave their informal consent to participate. Two types of the shoes were selected to test - negative heel walking shoes and regular walking shoes. The two types of shoes were similar in construction and materials except for the heel height. The negative heel walking shoes lifted the forefoot part of the sole and resulted in 10 degree of dorsiflexion. The heel of the regular walking shoes was higher and gradually lowered to the horizontal level at the toe part of the shoe, resulting in 10 degrees of plantarflexion.

Measurement Each subject participated two trials of test that were randomly assigned - walking in negative heel walking shoes and regular walking shoes. Subjects were instructed to walk for 20 min at 1.33m/s speed on a treadmill, which is a comfortable speed thought by the subjects in a pilot test. For each subject, test trials were randomly assigned to different testing days in the respective situations. For determining the energy cost of walking of the subjects, ventilatory parameters were measured with a cardiovascular system (Oxycon Champion, Yeager, Germany). Oxygen consumption (VO_2) and respiratory quotient (RQ) of the subjects were measured to calculate the individual energy expenditure of all subjects. The subjects were connected to the Oxycon with a flexible tube making an airtight seal to a facemask. Heart rate of the subjects was recorded throughout the test. All parameters measured were automatically calculated as an average of data during a time span of 30 s and stored in the personal computer (PC) connected to the Oxycon. Before data collection, the subject was asked to walk in the shoes to be tested on treadmill for 2 minutes for adaptation and practice purpose. All measured parameters were recorded throughout the testing period. Only the data measured at 1^{st} min, 5^{th} min, 10^{th} min, 15^{th} min and 20^{th} min after starting walking were used to calculate the energy expenditure basing on the measures of VO_2 and RQ in accordance with the formula by Weir (1949). The data recorded while standing on the treadmill (0 min) served as the baseline control.

Statistical analysis Differences in the measured parameters between negative heel shoes and regular walking shoes were examined with paired-samples t test. The 0.05 probability level was used for all tests as the criterion value in determining the presence or absence of statistically significant results.

RESULTS AND DISCUSSION

The main findings of the present study were the increase heart rate and energy expenditure while walking in negative heel shoes compared to walking in regular shoes. Figure 1 illustrates that walking 20 min in negative heel shoes induced a significant higher heart rate responses than that measured walking in regular walking shoes. Figure 2 illustrates the energy expenditure changes during walking for 20 min in different shoes and shows there were significant differences in energy expenditure ($P<0.01$) during walking in negative heel shoes and regular walking shoes. The differences of energy expenditure walking in different shoes were appeared after walking 5 min and continued to the end of the testing, with the exception of the value measured at 15th min post walking. The mean heart rate and energy expenditure showed the same trends. The higher values of energy expenditure and heart rate during walking in negative heel shoes can be explained by the shoe's effect of mimicking walking up-hill. Biomechanical studies showed that while walking in negative shoes, the foot is placed in a dorsiflexion position and the extension angles were less at the take off moment, resulting in a shorter stride length. To maintain a given speed, the cadences must increase, which in turn, will increase the energy cost of gait. Physiological study of energy expenditure during level walking and uphill walking found that there is a significant higher energy expenditure while up hill walking at 1.0 ± 0.3 m/s speed compared with those measured in level walking and downhill walking (Minetti, et al., 2002). The data from this study indicated that walking in negative heel shoes with the forefoot tilted 10 degree in dorsiflexion can increase heart rate responses and energy expenditure compared to walking with regular shoes.

Table 1 Anthropometric and biological characteristics for all the subjects

Subject (no.)	Sex	Age (year)	Body mass (kg)	Height (cm)
1	F	29	58	165
2	F	30	64	164
3	F	45	62	163
4	F	26	53	164
5	F	33	63	163
6	F	34	50	166
Mean (± SD)		32.8 (6.6)	58.3 (5.8)	164.2 (1.2)

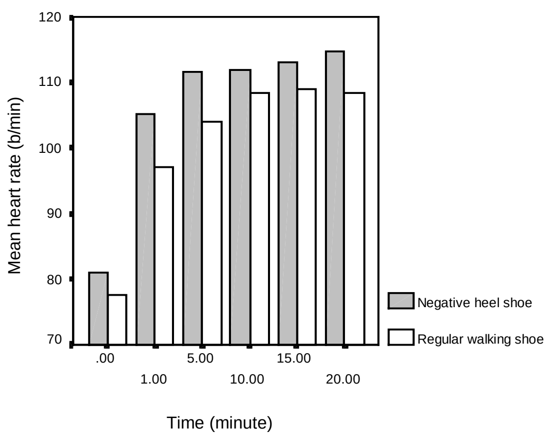

Figure 1 Heart rate responses to walking for 20 min in negative heel shoes and regular walking shoes. Significant differences (P<.05 or .01) were found between the two types of shoes at the all measuring time points except 0 min.

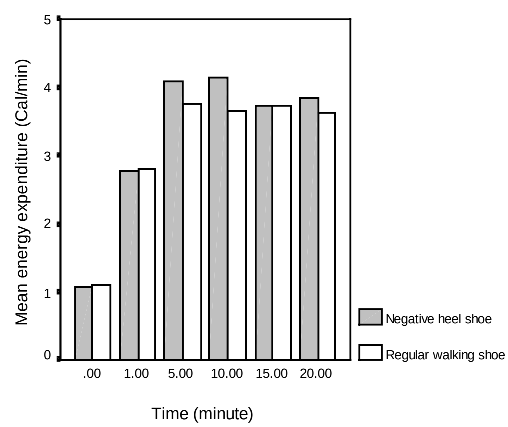

Figure 2 Energy expenditure during 20 min walking in negative heel shoes and regular walking shoes. Significant differences (P<0.01) were found between the two types of shoes at the 5th min, 10th min, and 20th min walking 5 min after walking.

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