Physiological Impact of Heeled Footwear

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Abstract

The study was designed to determine the impact of wearing heeled footwear on the various physiological parameters viz. heart rate, energy expenditure and centre of gravity of the wearer's body; wearing flats following 3 different heel heights of 3, 5 and 7 inches in static and dynamic conditions respectively. Healthy, able bodied, young college girls [age-18-23 yrs.] accustomed to walking in heels were purposely selected as subjects for the experiment. Results revealed that during the static phase, heart rate increased with increase in heel height to 3, 5 and 7 inches; while in the dynamic phase the heart rate initially decreased with the first increase in heel height to 3" but an increase in heel height beyond 3" (i.e. to 5" and 7") significantly increased heart rate. Further, as heel height increased energy expenditure decreased for a heel height up to 3" in both static and dynamic conditions; any further increase in heel height increased energy expenditure.

A significant shift in the centre of gravity was observed in the Z-axis only as the heel height increased.

Thus, it was concluded that physiologically the 3" heel height was economical; and are therefore recommended when essential to be in heeled footwear regularly.

KEYWORDS: Heel height, heart rate, energy expenditure and centre of gravity.

INTRODUCTION

The activity of walking is an outcome of a complex interaction of the brain, spinal cord, muscles, foot, hips and pelvis (1,3,5); and efficient walking is said to be achieved by forward transmission of one limb to the next using the least amount of energy (6). A condition that alters the physiological and functional (2) demands placed on the body is the use of heeled footwear.

Walking in high heeled footwear is not only observed to require more efforts but is also noted to have a profound impact (7) on the balance, posture, gait kinematics (Hong, Lee, & Chen 2007; Lee, Jeong & Freivalds, 2001) and foot stability (Gefen, Ravid, Itzchak & Arcan 2001) of the wearer. Additionally, high heel wearing is strongly linked with alterations in the calf muscles; reduction & stiffness in the Achilles tendon; further contributing to a reduction in the active range of motion of the ankle joint (7) and making the activity of walking a challenging task for most wearers (Godwin et. al 2004 & Marco Nairci 2010).

Physiological parameters such as energy expenditure, oxygen consumption and centre of gravity are also noted to undergo changes when exposed to wearing high heeled footwear. Ebbeling, et al., (4) observed an increase in energy expenditure in heel heights of 50.8mm; Mathews and Wooten (7) also reported an increase in energy expenditure in 10 females who walked on a treadmill wearing high-heeled footwear. Off-late, Li and Gu (2012) concluded that jogging wearing high heel shoes could directly increase energy consumption, causing neuromuscular fatigue.

It is evident from scientific reviews that long-term high heel use may bring about certain physiological changes, compromise muscle efficiency in walking and cause discomfort and muscle fatigue with increased risk of strain injuries (8). However, greater number of studies have focussed on exploring the effects of high heeled footwear on lower limb function and loading, with very few reporting about their effects on the physiological parameters like energy consumption and centre of gravity.

Further, it is also believed that walking in low-heeled footwear provides a normal heel strike and a smooth forward transmission of the limb thereby conserving energy; in comparison to walking in high heeled footwear which results in an early heel strike (6) Thus, investigating the impact of heeled footwear on various physiological parameters like heart rate energy consumption and centre of gravity becomes essential and provide basis for heel wearers to choose the right height of heel and may allow non-heel wearers to adopt the practice of wearing heels. Therefore, the study was aimed to evaluate the impact of heeled footwear on various physiological parameters.

OBJECTIVES:

1. To find out the physiological cost of wearing heeled footwear on human body
2. To investigate the effect of wearing different heels heights on the centre of gravity of the human body.

METHODOLOGY:

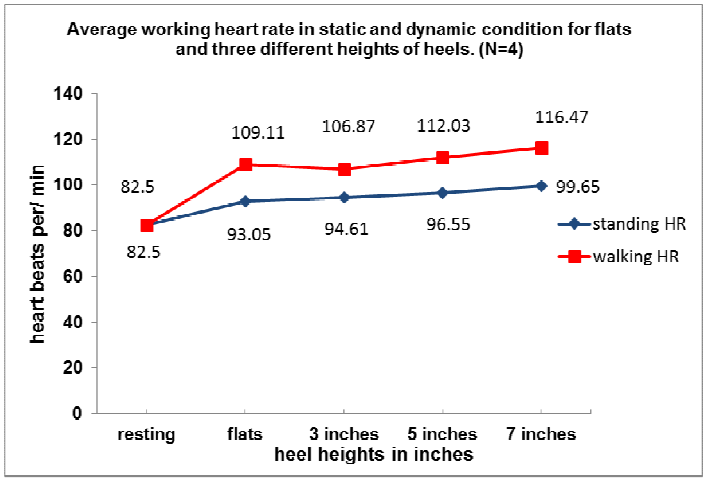
Four healthy college students (21-23years) for energy expenditure and three for centre of gravity analysis were purposely selected as subjects. Standard sandals were constructed for the study of three different heel heights viz. 3”, 5” & 7”.

A K4b2 analyser machine was used for measuring heart rate and energy expenditure at different heel heights i.e. flat (0.39”), 3”, 5” and 7” under 3 conditions standing 4mins, walking on the treadmill for 4mins. at a speed of 2.2km/hr. followed by a recovery of 4mins.

Whole body C.G. in static condition on flats and three different heights of heels were determined using photographic technique. Average age, body weight and height of the subjects were 22 years, 52.6kg and 152cm respectively. Markers were attached to body landmarks; with a Nokia D150 camera photograph of each subject was first taken from the front side (to get the frontal view) followed by a side view photograph with each pair of sandals of four different heights. The photographs were analysed through CG analysis software to find out any shift in CG.

RESULTS AND DISCUSSION

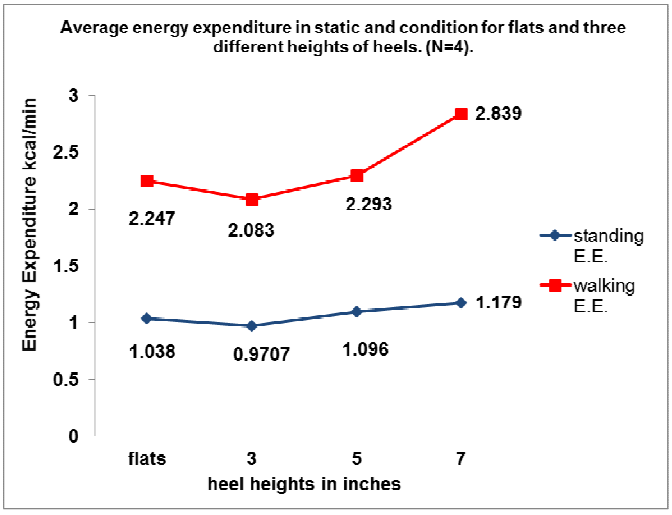
Graph 1: Average working heart-rate in static & dynamic condition for different heel heights (N=4)



It is observed that in static phase as heel height increased heart rate also increased but the pace of increase was different with respect to heel heights; the least was when the heel height increased from flats to 3" i.e. 1.56 bpm.; from 3" to 5" it is 1.94 bpm. and from 5" to 7" it is 3.10 bpm.

In dynamic phase, heart rate at first actually decreased with the initial increase in heel height from flats to 3" (2.24 bpm.); increase in heel height from 3" to 5" is observed to be maximum (5.16 bpm) as compared to 5" to 7" wherein the increase is 4.44 bpm.

Graph 2: Average Energy Expenditure in static & dynamic conditions for different heel heights. (N=4)



In both static and dynamic phases it was observed that the energy expenditure at first decreased with the first increase in heel height to 3" (static – 0.673kcal/min; dynamic – 0.164 kcal/min.) and then increased with increase in heel height to 5" (static – 0.125 kcal/min; dynamic – 0.21 kcal/min) and 7" (static - 0.083 kcal/min; dynamic – 0.546 kcal/min).

Thus, it was concluded that a slight increase in heel height up to 3" was actually economical for the wearer as energy expenditure actually decreased with the initial increase in heel height.

Centre of gravity: Table 1a: Indicates the location of C.G. in Z axis

Heel height	C.G. Location- z axis %age –(front)	s.d.	s.d.
Flats (0.39")	59.72	±0.6	±1.51
3"	60.43	±0.78	±1.42
5"	60.89	±0.44	±4.69
7"	61.19	±0.56	±0.76

Table 1b: indicates the "t" values observed of C.G. Location in z axis for different heights of heels (N= 4)

z-axis (front)	0.39"(Flats)	3"	5"	7"
Flats		0.011 (s)	0.003 (s)	0.007 (s)
3			0.073 (ns)	0.047 (s)
5				0.107 (ns)

From Table 1b, it is observed that CG shifted as heel height increased from flats to all the three heights significantly; but for a shift from 3" to 5" the shift in CG was not significant (0.073) however a shift from 3" to 7" was significant (0.047); a shift from 5" to 7" was not significant (0.107).

In case of X-axis (side) as well as Y-axis (front) there is no significant shift in CG observed in all the cases. Thus, it was concluded that there was a slight shift in CG in the Z-axis while no significant shift was observed in the Y and X axis.

Subject's perception were also noted and analysed post the experiment which revealed: none of the subjects faced severe discomfort on wearing heels; subjects were comfortable up to a heel height of 3"; 5" heel was 'slightly' uncomfortable while 7"heel was 'somewhat' uncomfortable.

Movement slowed down to 'some' extent with heel height of 3", while 5"and 7" heels definitely slowed down movement.

(75%) of the subjects experienced foot pain 'somewhat' after removing heels while the remaining one-fourth (25%) reported to have experienced only 'slight' foot pain on removing heels.

It was thus, concluded that foot pain was experienced by majority of the subjects after removing heels.

CONCLUSION:

There was a direct relationship between heel height and heart rate. In static condition; heart beats per minute increased at a higher pace as the heel height increased, comparatively; the least increase was in the heel height to 3". In dynamic condition; an increase in heel height to 3" actually decreased heart beats per minute but an increase to 5" and 7" heel height significantly increased heart rate indicating more oxygen consumption.

For energy expenditure, it was found that as heel height increased energy consumption actually decreased with an increase in heel height up to 3" in both static and dynamic conditions. Any further increase in heel height increased energy expenditure considerably. A significant shift in CG in the "Z"-axis (front) was observed while no significant shift was found in the "Y" and "X" axis.

Thus it is recommended to those for whom heel wearing is a regular must to limit the heel height to 3''; anything beyond may be a health hazard.

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