The effects of high heeled shoes walking in on energy expenditure and oxygen consumption in healthy young female

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Received: December 07, 2021; Accepted: December 24, 2021

ABSTRACT

Background: Walking in high-heeled shoes is widespread dress behavior of women of modern society. It increases lower limb muscles activity and energy cost. The need to generate larger muscular forces during walking increases the metabolic demand, thus oxygen consumption (VO2) is increased when wearing high heels. Aims and Objectives: To access effect of high-heeled shoes on Energy Expenditure (EE) and VO2 in Healthy Young female. Materials and Methods: This cross-sectional study was conducted among fifty apparently healthy female students between the ages of 20 and 26 yrs. Resting arterial blood pressure and heart rate (HR), VO2, heat production, and EE were recorded. Then, subjects walked barefooted a distance of 76.5 meters in 2 min. Following the barefooted walk, cardiac and metabolic parameter were recorded again. The subjects walked 76.5 meters in high-heeled shoes of 2, 4, and 6 inches. These parameters were recorded immediately after 76.5 meters of walking in high-heeled shoes. Results: The results from the present study indicate that walking a distance of 76.5 meters barefooted resulted in a significant increase only in mean arterial pressure, HR and rate pressure product. The EE and VO2 after walking a distance of 76.5 meters in high-heeled shoes of 2, 4, and 6 inches heel heights was significantly higher than walking a distance of 76.5 meters barefooted. Conclusion: Walking barefooted required lesser effort than walking in high-heeled shoes of different heel heights. Effort should therefore be made to encourage women to reconsider the habitual use of high-heeled shoes.

KEY WORDS: Barefoot; Energy Expenditure; High Heeled Shoes; Oxygen Consumption

INTRODUCTION

Walking with high-heeled shoes is widespread dress behavior among 37–69% of women of modern society.1 Although it is uncomfortable and hazardous, most corporate women in managerial positions sacrifice comfort for high fashion with cost of pain and discomfort.2

It causes hyperextension of back and neck which leads to elevation of the pelvis, the trunk is tilted forward and strain is put on the back muscles.3 High heels are associated with higher vertical peak and anteroposterior ground reaction forces, increased knee moments peak, and smaller plantar flexion moments.4-6 In high heels, the duration of the stance phase, stride length, and step angle were all dramatically reduced.5,7,8 It shift the bodyweight on the forefoot and changes in the center of gravity which results in an increased risk of falling, back pain, neck pain, osteoarthritis, and foot deformities.9 The prolonged position of the foot in plantar flexion causes impairment and pain, not only to the ankle and knee joints but also to the pelvis and spine. Moreover, walking with high-heeled shoes increases lower limb muscles activity
and the energy cost. When walking in high heels, the need to generate higher muscular forces increases metabolic load, resulting in increased oxygen consumption (VO$_2$).

The present study aims to access effect of high heeled shoes on Energy Expenditure (EE) and VO$_2$ in Healthy Young female.

**MATERIALS AND METHODS**

This cross-sectional study was conducted in the Department of Physiology of Dr. N. D. Desai Faculty of Medical science and Research, Nadiad. Fifty apparently healthy female students between the ages of 20 and 26 years from Dr. N. D. Desai Faculty of Medical science and Research, Nadiad were enrolled in the study. All subjects had experience of wearing high-heeled shoes at least twice per week. Participants with foot-related disorders, orthopedic injuries, skin lesions, or abnormal vision were excluded. Informed consent was obtained from all subjects. Ethical approval for this study was taken from the institutional ethics committee.

**Experiment 1 - Walking 76.5 Meters Barefooted**

The age, height, and weight of the participants were recorded. The participants were instructed to lie down in a supine position for half an hour. The protocol of McArdle et al. and Jaja et al. was used to record resting arterial blood pressure (ABP) and heart rate (HR), VO$_2$, heat production (HP), and EE.

During supine position, the nose was connected to a 9-liter spirometer (SRI multipurpose spirometer) filled with 100% oxygen and with the soda-lime canister in place. The subjects breathed through one of the channels. The subjects were moved from ambient air to 100% oxygen in the equipment after acclimating to the device. The subjects respired quietly for 5 min at a drum speed of 25 mm/min and thereafter disengaged from the spirometer after obtaining the required graphical representation (i.e., the expiratory points).

After that, the participants walked 76.5 meters barefoot in 2 min. The individuals returned to a supine position after the barefooted walk to evaluate metabolic and cardiovascular parameters (ABP, HR, VO$_2$, HP, and EE).

**Experiment 2 - Walking 76.5 Meters in Different Heel Heights**

The procedure was repeated with the individuals wearing high-heeled shoes with heels of 2, 4, and 6 inches. Mean arterial pressure (MAP), HR, rate pressure product (RPP), VO$_2$, and EE were measured immediately after walking 76.5 meters in high-heeled shoes with three different heel heights. After walking, the participants were asked to take a half an hour rest. Three distinct shoes were worn, each with a heel height of 2, 4, and 6 inches. Each shoe was chosen primarily because of the similarity of construction at the forefoot and the pointed heel. Thus, the main difference between the three shoes was the height.

**Calculation of VO$_2$ and EE**

There were movement of the drum when the subjects were breathing through the spirometer, emphasizing the portion where the subjects were most relaxed. A straight line was drawn through the tips of the graph (i.e., the expiratory points).

The slope of the line was used to calculate the subject’s VO$_2$ (mL/min), which was then adjusted for temperature and pressure. VO$_2$ was multiplied by 0.893 (correction factor) and 4.8 to get HP (calorific value of oxygen). By dividing the heat generation by the body surface area, the EE (metabolic rate) was computed (m$^2$). SVP was multiplied by HR to get the RPP. The diastolic blood pressure was added to one-third of the pulse pressure to get the MAP (i.e., systolic blood pressure minus diastolic blood pressure).

**Statistical Analysis**

The data were collected with predesigned proforma and entered in Microsoft Excel 2010. The data was analyzed with Epi info version 7.1. Continuous data were presented with mean and standard deviation while categorial data was presented with frequency and percentage. Comparison of continuous data and categorial data between two groups were analyzed with Z test. $P < 0.05$ was considered as significant.

**RESULTS**

The subjects’ average age and BMI were 22.4 ± 0.2 years and 22.2 ± 0.6 kg/m$^2$, respectively.

**Cardiovascular/Metabolic Responses at Rest and After Walking 76.5 Meters Barefooted**

Table 1 shows the resting mean values for MAP, HR, RPP, VO$_2$, and EE. Walking a distance of 76.5 meters barefooted versus rested did not result in a significant change in VO$_2$ max and EE. However, while barefooted walking versus resting, MAP, HR and RPP were significantly greater.

**Cardiovascular/Metabolic Responses after Walking 76.5 Meters in 2, 4, and 6-Inch Heel Heights**

The cardiovascular responses of the participants during walking 76.5 meters barefooted and in high-heeled shoes of 2, 4, and 6-inch heel heights. The cardiovascular responses in various heel heights were significantly higher than barefooted walking in each case ($P < 0.05$). MAP was significantly higher in 6 inch heeled shoes than 4 inch and 2 inch heeled shoes. Similarly, HR was significantly higher in 2 inch heeled shoes than 4 inch and...
6 inch heel shoes. However, there was no significant difference in RPP after walking a distance of 76.5 meters in high-heeled shoes of 2, 4, and 6-inch heel heights [Table 2].

Table 3 demonstrates the subjects’ metabolic (VO₂ and EE) responses to walking 76.5 meters barefoot and in high-heeled shoes with varying heel heights (2, 4, and 6 inches).

The EE and VO₂ after walking a distance of 76.5 meters in high-heeled shoes with heel heights of 2, 4, and 6 inches were considerably greater than while walking the same distance barefooted ($P < 0.05$). Six inch heeled shoes had significantly greater VO₂ than 4 inch and 2 inch heeled shoes. In 2 inch heeled shoes, EE was much higher than in 4 inch and 6 inch heeled shoes.

**DISCUSSION**

This study investigated changes in MAP, HR, VO₂, and EE in healthy young women at rest and walking a distance of 76.5 meters within 2 min barefooted and with shoes of different heel heights.

According to the findings of this study, walking 76.5 meters barefooted resulted in a significant increase in only MAP, HR, and RPP. The subjects’ VO₂ max and EE were not affected by walking barefoot versus resting. Thus, the transition from rest to light physical activity like walking was not associated with increasing metabolism. Physiological expectation of an activity (such as barefooted walking) that would expect to have no influence on the participant’s perception of effort and/or EE given the minimal generation of muscular force during walking.$^{[14,15]}$

The EE and VO₂ after walking a distance of 76.5 meters in high-heeled shoes with heel heights of 2, 4, and 6 inches were considerably greater than while walking the same distance barefooted ($P < 0.05$). VO₂ was significantly higher in 6-inch heeled shoes than 4 inch and 2-inch heeled shoes. EE was significantly more in 2-inch heeled shoes than 4 inch and 6-inch heeled shoes. There was a significant difference in EE and VO₂ with walking barefooted and walking in high heel shoes of 2, 4, and 6-inches height.

This suggests that walking with higher heel heights puts the subjects’ cardiovascular and metabolic systems under more stress. Walking in high-heeled shoes, according to Odebiyi et al.$^{[2]}$ places an excessive load on the cardiovascular and metabolic systems, resulting in increased VO₂ and EE during locomotion. In addition, as the heel heights increased, the cardiovascular responses, oxygen intake, and EE of the participants increased. It could imply that walking in

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**Table 1:** Cardiovascular and metabolic responses at rest and after walking a distance of 76.5 meters barefooted

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Resting values</th>
<th>Walking barefooted</th>
<th>$P$-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP</td>
<td>64.62±4.31</td>
<td>72.83±5.10</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>HR</td>
<td>73.90±6.21</td>
<td>76.72±1.61</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>RPP</td>
<td>6770.23±954.23</td>
<td>7234.22±1023.30</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>VO₂</td>
<td>0.84±0.22</td>
<td>0.82±0.20</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>EE</td>
<td>2.10±0.31</td>
<td>2.10±0.23</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

MAP: Mean arterial pressure, HR: Heart rate, RPP: Rate pressure product, VO₂: Oxygen consumption, EE: Energy expenditure

**Table 2:** Comparison of cardiovascular responses after walking a distance of 76.5 meters barefooted and in shoes with different heel heights

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean±SD</th>
<th>$P$ value (Barefoot vs. Others)</th>
<th>$P$ value (2 inch vs. Others)</th>
<th>$P$ value (4 inch vs. Others)</th>
<th>$P$ value (6 inch vs. Others)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP</td>
<td>70.63±5.20</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>2 inch</td>
<td>73.10±5.70</td>
<td>&lt;0.05*</td>
<td>NA</td>
<td>&gt;0.05</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>4 inch</td>
<td>75.10±4.22</td>
<td>&lt;0.05*</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>6 inch</td>
<td>78.20±5.43</td>
<td>&lt;0.05*</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>NA</td>
</tr>
<tr>
<td>HR</td>
<td>69.3±5.11</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>2 inch</td>
<td>72.10±4.25</td>
<td>&lt;0.05*</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>4 inch</td>
<td>74.12±4.33</td>
<td>&lt;0.05*</td>
<td>NA</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>6 inch</td>
<td>76.23±6.32</td>
<td>&lt;0.05*</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>RPP</td>
<td>69.3±5.11</td>
<td>NA</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
<td>&lt;0.05*</td>
</tr>
<tr>
<td>2 inch</td>
<td>72.10±4.25</td>
<td>&lt;0.05*</td>
<td>NA</td>
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<td>NA</td>
<td>&lt;0.05*</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

MAP: Mean arterial pressure, HR: Heart rate, RPP: Rate pressure product, *values depicts statistically significant difference
high-heeled shoes causes an unnecessarily high increase in MAP, HR, RPP, VO\textsubscript{2} max, and EE and that the physiological burden rises as the heel height rises.

It could imply that walking in high-heeled shoes causes an unnecessarily high increase in MAP, HR, RPP, VO\textsubscript{2} max, and EE, and that the physiological burden rises as the heel height rises. Walking in heeled shoes reduced stride length and velocity, increased stance time percentages, and reduced range of motion, according to Stefanyshyn et al.\textsuperscript{[16]} The body increases the participation of the principal plantar flexor muscles (gastrocnemius and soleus) to compensate for the altered gait, which involves increased activation of the rectus femoris. As a result of the increased metabolic activity of these muscles, VO\textsubscript{2} and EE may rise.

Nadège \textit{et al.}\textsuperscript{[17]} reported that walking in heels with a height of 4.13 cm ± 0.34 at a step frequency freely chosen interferes less with the locomotor pattern and HR optimization in women. When compared to walking barefooted, walking in heel heights puts higher strain on the respiratory muscles.

Ebbeling \textit{et al.}\textsuperscript{[18]} reported that high-heeled shoes alter the ankle and knee joint's orientation. Heel heights more than 5.08 cm can have a significant impact on lower extremity mechanics, which can affect energy cost of gait. It increases vertical loading by changing the angular patterns of the ankle and knee. The kinematic alterations, on the other hand, prevent attenuation of this vertical stress since balancing becomes more crucial at higher heel heights.

CONCLUSION

Walking barefoot required less work than walking in high-heeled shoes of various heel heights, with the higher the heel heights appearing to require more effort. The greater the effort necessary for locomotion while walking in high-heeled shoes of various heel heights. When compared to walking barefooted, it requires greater effort from the respiratory muscles. As a result, efforts should be undertaken to persuade women to reconsider their habitual usage of high-heeled shoes. To maintain comfort and limit the risk of injury, walking in shoes with modest heel heights (<2 inches) is recommended.

ACKNOWLEDGMENT

I express my sincere gratitude to Dr. Varsha Joshi, Professor and Head for sharing his wisdom during the study. I am thankful to Dr. Shaista Saiyad, Assistant Professor for his suggestions. I want to thank wholeheartedly to the study participants without whom this study would not have been completed.

REFERENCES

7. Simonsen EB, Svendsen MB, Norreslet A, Baldwinsson HK,


How to cite this article: Parmar J, Thaker R, Joshi J, Jain N. The effects of high heeled shoes walking in on energy expenditure and oxygen consumption in healthy young female. Natl J Physiol Pharm Pharmacol 2022;12 (Online First). DOI: 10.5455/njppp.2022.12.1249202124122021

Source of Support: Nil, Conflicts of Interest: None declared.