EFFECTS OF HEEL HEIGHTS AND SHOE INSERTS ON STEP COUNTS AND PERCEIVED COMFORT AMONG FEMALE UNIVERSITY STUDENTS.

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ABSTRACT

Background: Studying the effects of heeled shoes and shoe inserts on step counts and perceived comfort may advance shoe design and minimize adverse effects on human musculoskeletal system such as discomfort, sprained ankles, and lower back pain. Therefore this study was conducted to determine the association between heel height and use of shoe inserts with step counts as well as perceived comfort among female undergraduate students of a public university.

Methodology: Through random sampling method, a total of 64 respondents participated with 32 healthy female undergraduates represent the heeled-shoes wearing experienced group and another 32 respondents formed the non-experienced group. The heel heights used were 2.0 cm (flat), 4.0 cm (low), and 6.0 cm (high). The shoe-insert conditions used were shoe only, heel cup, arch support, and total contact insert (TCI). Respondents walked on treadmill for each experimental condition. Sociodemographic data, perceived discomfort rating and steps count were collected using questionnaire, Visual Analogue Scale (VAS) scale and an OMRON pedometer respectively. Reliability of instrumentation was measured and Chronbach’s alpha values for VAS scale were in average of 0.818.

Results: With overall response rate of 87.5%, the perceived discomfort increases as heel height increases with significant difference among experienced group wearing low and high-heeled shoes (p = 0.0178). As for step count based on heel heights and shoe inserts, there was no significant different in the step counts between the two groups (P>0.05). However it was noted that the experienced group had higher step count compared to non-experienced group and different shoe inserts were able to decrease the number of steps per minute of both groups.

Conclusion: Experienced group of female undergraduates with previous wearing experience, flat heeled-shoes, and total contact insert offered lowest number of step counts, and lowest perceived discomfort rating when compared to other heel heights and insert condition.

Keywords: Heel heights, Shoe inserts, Step count, Perceived comfort
1.0 Introduction

In a tomb of Tebas in Old Egypt, and dated back to 1000 BC, the first precursors of stiletto heels were discovered (Wilson, 2006), where it was thought to provide the feeling of higher social status as well as to satisfy their desire to be more beautiful. For more than a millennium despite the advancement of technology, the perception of stiletto shoes still stands strong as proven by a study in Taiwan that reported a survey of shoe choice showed 53% of females in average wear high-heeled shoes between 1 and 8 hours per day on a daily basis. The reasons for wearing this style of footwear vary greatly with many women stating that they feel more confident and glamorous from the extra height gained (Lee & Hong, 2005). However despite the glamorous feeling, Lee, Jeong & Feivalds (2001) surveyed 200 females who regularly wore high-heeled shoes found that 58% of this population experienced perceived discomfort whilst wearing the shoes. In addition, perceived discomfort such as consequent of musculoskeletal discomfort, sprained ankles, lower back pain, due to increased spinal curvature, and leg pain, due to added weight placed on the toes contribute to the existing ergonomic problems (Lee & Hong, 2005). As a result, foot discomfort produced a substantial cost to health system and industrial productivity, with treatment and missed time from work in North America alone estimated to cost more than US $100 billion per year (Sahar et al., 2007). To overcome this problem, a modification in shoe heights and application of shoe inserts in different regions of foot was found to improve the perceived comfort; a finding similar to Mündermann, Stefanyszyn, & Nigg (2001) that reported a higher perceived comfort score in subjects with the use of elastic and soft insert material rather than viscosus and hard materials. Elsewhere studies also showed that the prevalence of foot problems among female wearing high-heeled shoes is approximately 83% in females and 90% of them contribute to the nearly 800,000 annual surgeries for neuromas, bunions, and hammer toes (Dawson et al., 2002).

Nowadays high heels are more typically worn by females if compared to males, with heights varying from kitten heel to a stiletto heel or more. In order to show good image and to be more beautiful in formal places such as university, female undergraduates tend to wear high heels. However, studies in Malaysia on effects of wearing high-heeled shoes are limited and this study aimed to investigate a young homogenous asymptomatic population, i.e the female participants in determining whether increasing heel height and use of shoe inserts changes the step counts and perceived comfort during walking.

2.0 Materials and Methods

This study was conducted between November to December 2013 among female undergraduate students in a public university. Students were randomly sampled based on the name list of female undergraduates studying at the faculty which was obtained from the faculty management. This study was designed to determine whether heel heights and shoe inserts has effect on steps count and perceived comfort among them. The study sample consisted of two groups of female undergraduates who were experienced group: had worn low or high-heeled shoes at or more than one time per week for at least 1 year; while the non-experienced group were those who had no or less than 1 year experience in wearing low or high-heeled shoes (de Castro et al., 2010). Based on group comparison sample calculation and study by Curran, Holliday, & Watkeys 2010, the estimated sample size was 32 for experienced group, and 32 for non-experienced group (total 64). The study inclusion criteria
was female undergraduate aged between 18 years and 26 years with normal BMI (18.50 – 24.99) and had no physical disability or foot discomfort problem. However, those who were pregnant, suffered injury to the body part during preceding year, or use of bandages which prevent direct contact of shoe inserts with skin were excluded.

2.1 Study instruments and procedures

2.1.1 Heel heights and shoe inserts

The respondents experienced three heel heights (Figure 2.1): a flat (2.0 cm), a low (4.0 cm) and a high heel (6.0 cm) while for shoe inserts, each participant received four insert conditions (Figure 2.2): (1) shoe only; (2) heel cup; (3) arch support; and, (4) Total Contact Insert (TCI).

![Figure 2.1: The shoes of 3 different heel heights are used in this study. From left to right: a flat (2.0cm), a low (4.0cm) and a high heel (6.0cm).](image1)

![Figure 2.2: The types of shoe inserts and their support positions.](image2)

2.1.2 Step count

The NordicTrack Apex 4600 treadmill was used to make walking steps systematically. Each participant walked on a treadmill for 5 minutes at 130 cm/s for each heel heights and shoe insert conditions. The speed of 130 cm/s was used because the comfortable speeds reported in previous studies about high heels ranged from 122 to 140 cm/s (Esenyel et al., 2003). To prevent fatigue, each participant took a 5 minutes rest in between the condition. The Omron Digital Pedometer HJ-105 was used to display step counts and step distance in the study. The accuracy of Omron Digital Pedometer HJ-105 was adjusted at ±5% (the differential of 5 steps more or less against 100 steps). It was attached to the belt or the top of respondents’
waistband and before data began the step number was cleared. In addition the accuracy of Omron Digital Pedometer HJ-105 was adjusted in a normal condition where the user walks straight on level ground. A study by De Cocker et al., 2012 showed that intra-instrument reliability was proven for controlled tests (ICC = 0.14–0.96).

2.1.3 Perceived discomfort rating

The Visual Analogue Scale (VAS) is a measurement instrument that measures a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured. It is often used in epidemiologic and clinical research to measure the intensity or frequency of various symptoms and in this study, the VAS was used to rate the perceived comfort for each experimental condition. Comfort was rated by a ruler that consisted of a 150mm VAS with the left end of the scale labeled ‘not comfortable at all’ (0 comfort point) and the right end labeled ‘the most comfortable condition imaginable’ (15 comfort points). (Mündermann et al., 2002).

![150mm Visual Analogue Scale (VAS)](image)

**Figure 2.3:** 150mm Visual Analogue Scale (VAS)

2.2 Statistical analysis

IBM SPSS Version 19.0 was used to analyze the data variables. Univariate data were presented as frequencies and percentages or mean and SD. Normality of data distribution was tested by Shapiro-Wilk normality test and showed all data to have a normal distribution. Independent samples T-test was used to compare the mean difference of study variables, whilst Fisher’s Exact test compares frequencies between experienced and non-experienced groups of female undergraduates. The level of significance was set at 0.05 for all analyses.

2.3 Ethical

This study was approved by the Ethics Committee for Research involving Human Subjects (JKEUPM), Universiti Putra Malaysia. Written informed consent was obtained from each respondent voluntarily and confidentiality of the data collected was maintained throughout the study period.

3.0 Results and Discussion

3.1 Response rate and sociodemographic characteristics

The overall response rate is 87.5%. The non-response were due to those who had body injury within past 1 year (3.1% of respondents suffered from elbows and wrists/hands injury within past 1 year) and approximately 9.4% of respondents did not fulfil the inclusion criteria of normal BMI thus were excluded from the study. Table 3.1 tabulates the comparison of experienced and non-experienced group among female undergraduates by socio-demographic
characteristics and were found to be homogeneous by socio-demographic characteristics (P > 0.05).

**Table 3.1:** Distribution of experienced and non-experienced group among female undergraduate students by socio-demographic characteristics

<table>
<thead>
<tr>
<th>Socio-demographic Characteristics</th>
<th>Experienced Group (N=32)</th>
<th>Non-experienced Group (N=32)</th>
<th>t</th>
<th>x²</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>21.59 (0.88)</td>
<td>21.81 (1.12)</td>
<td>0.871</td>
<td>-</td>
<td>0.387*</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Malay</td>
<td>19 (59.4)</td>
<td>21 (65.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese</td>
<td>11 (34.4)</td>
<td>9 (28.1)</td>
<td></td>
<td></td>
<td>0.944b</td>
</tr>
<tr>
<td>Indian</td>
<td>1 (3.1)</td>
<td>1 (3.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>1 (3.1)</td>
<td>1 (3.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Height (m)</strong></td>
<td>1.58 (0.05)</td>
<td>1.59 (0.06)</td>
<td>0.857</td>
<td>-</td>
<td>0.395a</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>55.83 (8.17)</td>
<td>54.00 (6.96)</td>
<td>-0.964</td>
<td>-</td>
<td>0.339a</td>
</tr>
<tr>
<td><strong>Body Mass Index, BMI (kg/m²)</strong></td>
<td>22.53 (3.37)</td>
<td>21.48 (2.67)</td>
<td>-1.385</td>
<td>-</td>
<td>0.171a</td>
</tr>
</tbody>
</table>

*a* Significant at P < 0.05

a Independent-Samples t test

b Fisher’s Exact Test

### 3.2 Perceived discomfort with shoe types among respondents

Figure 3.1 presents the feeling of respondents after wearing different heights of heeled-shoes. It was noted that perceived discomfort increases as heeled-shoes increases. Those who wore flat heeled-shoes reported the most comfortability with 68.8% from non-experienced group and 53.1% from respondents of the experienced group felt very comfortable while wearing it. While among the respondents from experienced group who have ever worn low-heeled and high-heeled shoes, the feeling of uncomfortable while wearing it increases to approximately 40% and 50% respectively. Fisher’s exact test shows that there was a significant difference among experienced group by feeling after wearing low and high-heeled shoes (P = 0.0178).
Figure 3.1: Distribution of experienced and non-experienced group among female undergraduates by feeling after wearing heeled-shoes (Significant at p < 0.05)

Wearing high-heeled shoes for walking generates a force spike at initial ground contact (i.e., impact force) and the force is then transmitted up to the skeleton as a ‘shock wave’. This shock wave appeared to damage soft tissues, which may result in perceived discomfort of leg and back-pain complaints and eventually lead to degenerative joint disorders (Dawson et al., 2002). Moreover, heel height also has an effect on the foot pressure distribution and vertical impact force. Reports indicated that high heel height generates greater vertical impact force with lower perceived comfort, whereas flat shoes tend to produce lower impact force thus have higher perceived comfort (Chiu & Wang, 2007).

Previous studies have demonstrated that wearing high-heeled shoes modifies gait kinematics and kinetics. Walking in high-heeled shoes alters lower-extremity joint function. Also, it raises the peak pressure in the forefoot and shifts peak pressures from the third, fourth and fifth metatarsal heads to the first and second and thus reduced the perceived comfort (Esenyel et al., 2003). A person wearing high heeled-shoes without shoe inserts may lose his or her natural ability to attenuate the shock waves and therefore may increase risk of degenerative joint disorders (Kerrigan et al., 2005).

3.3 Step count among respondent

Table 3.2 presents the result of average steps count (steps) per minute for heel heights & shoe insert condition among experienced and non-experienced groups. For flat, low and high-heeled shoes, there were no significant difference between average steps count (steps) per minute for heel heights among experienced and non-experienced groups. However, experienced group had increased number of average step counts per minute for flat (1.1%), and low-heeled shoes (1.5%); whilst decreased number of average step counts per minute for high-heeled shoes (4.2%) compared to non-experienced group. Also, there was no significant difference between average steps count (steps) per minute for shoe insert conditions (arch support, heel cup and total contact insert) among experienced and non-experienced groups.
Flat-heeled shoes with total contact insert among non-experienced group achieved lowest number of average step counts per minute, and marked reduced steps (2.9%) compared to experienced group.

**Table 3.2:** Difference of average steps count (steps) per minute for heel heights and shoe insert conditions between experienced and non-experienced groups

<table>
<thead>
<tr>
<th>Heel Heights &amp; Shoe Inserts</th>
<th>Non-experienced Group (N=32)</th>
<th>Experienced Group (N=32)</th>
<th>t</th>
<th>p-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat-heeled Shoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoe Only</td>
<td>154.31 ± 20.60</td>
<td>155.97 ± 12.47</td>
<td>-0.389</td>
<td>0.699</td>
<td>-10.203 – 6.890</td>
</tr>
<tr>
<td>Arch Support</td>
<td>153.53 ± 18.81</td>
<td>156.28 ± 16.48</td>
<td>-0.622</td>
<td>0.536</td>
<td>-11.588 – 6.088</td>
</tr>
<tr>
<td>Heel Cup</td>
<td>149.19 ± 16.99</td>
<td>154.91 ± 16.43</td>
<td>-1.369</td>
<td>0.176</td>
<td>-14.071 – 2.634</td>
</tr>
<tr>
<td>TCI</td>
<td>149.06 ± 18.93</td>
<td>153.38 ± 14.40</td>
<td>-1.026</td>
<td>0.309</td>
<td>-12.717 – 4.092</td>
</tr>
<tr>
<td>Low-heeled Shoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoe Only</td>
<td>156.34 ± 20.53</td>
<td>158.66 ± 12.17</td>
<td>-0.548</td>
<td>0.586</td>
<td>-10.745 – 6.120</td>
</tr>
<tr>
<td>Arch Support</td>
<td>155.19 ± 17.92</td>
<td>157.19 ± 16.50</td>
<td>-0.464</td>
<td>0.644</td>
<td>-10.607 – 6.607</td>
</tr>
<tr>
<td>Heel Cup</td>
<td>149.63 ± 16.58</td>
<td>155.34 ± 15.98</td>
<td>-1.405</td>
<td>0.165</td>
<td>-13.857 – 2.419</td>
</tr>
<tr>
<td>TCI</td>
<td>149.56 ± 18.88</td>
<td>153.88 ± 14.37</td>
<td>-1.028</td>
<td>0.308</td>
<td>-12.698 – 4.073</td>
</tr>
<tr>
<td>High-heeled Shoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoe Only</td>
<td>164.69 ± 23.88</td>
<td>171.88 ± 24.35</td>
<td>-1.192</td>
<td>0.238</td>
<td>-19.240 – 4.865</td>
</tr>
<tr>
<td>Arch Support</td>
<td>163.59 ± 15.52</td>
<td>164.81 ± 15.67</td>
<td>-0.313</td>
<td>0.756</td>
<td>-9.012 – 6.574</td>
</tr>
<tr>
<td>Heel Cup</td>
<td>157.56 ± 18.35</td>
<td>164.34 ± 21.01</td>
<td>-1.375</td>
<td>0.174</td>
<td>-16.640 – 3.078</td>
</tr>
<tr>
<td>TCI</td>
<td>159.03 ± 19.90</td>
<td>160.06 ± 18.90</td>
<td>-0.213</td>
<td>0.832</td>
<td>-10.729 – 8.666</td>
</tr>
</tbody>
</table>

*Significant at P < 0.05

Previous study by Lythgo, et al. (2009) shows that on average, participants took 165.0 ± 51.5 steps in the barefoot condition and 155.0 ± 52.0 steps per minute when wearing shoes. However, participants of the study wore athletic shoes or runners commonly used for walking, and without shoe inserts. Limited studies have examined the effects of heel heights and shoe insert conditions on step counts. An increase in heel height will plantar flexes the foot, flexes hip and knee. These angular changes resulted in shorter stride length which result in the increased of step count. Taking more steps in high-heeled shoes however may be a negative factor since more steps may result in higher sagittal and varus knee torques which in turn leads to joint damage. Moreover, longer activation times of rectus femoris and contraction of other lower limb muscles may also be linked to longer stride patterns (Esenyel et al., 2003; Lee & Hong, 2005).
3.4 Respondents preference on heel heights and shoe insert conditions

Figure 3.2 demonstrates individual preference among the three different heel heights and four different shoe insert conditions. About 96.9% from non-experienced group and 87.5% from experienced group selected flat heel as their most preferable heel height. Only 3.1% from experienced group preferred high-heeled shoes for daily use. When the respondents were asked about preferable shoe insert conditions, 56.3% from non-experienced group and 71.9% from experienced group chose total contact insert as their most preferable shoe insert. It was then followed by arch support (21.9% for non-experienced group; 18.7% for experienced group), heel cup (15.6% for non-experienced group; 6.3% for experienced group), and shoe only (6.2% for non-experienced group; 3.1% for experienced group). However, there was no significant difference for the individual preference among experienced and non-experienced group (Fisher χ² Exact test; P>0.05).

![Figure 3.2: Individual preference among the three different heel heights and four different shoe insert conditions](image)

The types of shoe inserts used in this study are heel cup, arch support, and total contact inserts (TCI). The results show that there was lowest score of perceived discomfort rating for flat, low and high heeled-shoes with total contact insert. Flat-heeled shoes with total contact insert marked lowest score of perceived discomfort rating. This is consistent with a study done by Curran, Holliday, & Watkeys (2010) where they looked at energy consumption based on heart rate, oxygen consumption steps count whilst walking on treadmill and found that comfort rating together with energy consumption improved with the use total contact shoe insert.
Previous study (Lee & Hong, 2005) showed that a heel cup is effective in reducing heel pressure and the magnitude of the heel strike impact thus reduced perceived discomfort rating. An arch support was designed to resist depression of foot arch during weight bearing through skeletal support, thereby decreasing tension in the plantar aponeurosis and improved comfort level. Last but not least, a total contact insert (TCI) provided total pressure relief in the heel and forefoot regions (Chen, Ju & Tang, 2003). The use of inserts is effective in redistributing pressure beneath foot and absorbing energy in terms of reducing impact force and then improving perceived comfort level. Various inert designs demonstrate different kinetic modification during gait (Lee & Hong, 2005).

4.0 Conclusion and recommendation

This study indicates that more than half of respondents feel uncomfortable while wearing high-heeled shoes. Different heel heights and shoe insert conditions have significant effects to step counts and perceived discomfort rating. Majority of respondents selected flat heel as their most preferable heel height, and total contact insert as their most preferable shoe insert. Increasing heel height increases step counts and increases perceived discomfort rating during walking. Usage of 3 types of shoe inserts showed a decrease in step counts and perceived discomfort rating. A total contact insert (TCI) combined with heel-cup and arch-support mechanism for high-heeled shoes would be effective for an improvement in footwear comfort.

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Declaration of conflict of interest

I/we author(s) of the article declare that there is no conflict of interest regarding publication of this article.

References:


