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The Influence of Walking Speed and Heel Height on Peak Plantar Pressure in the Forefoot of Healthy Adults: A Pilot Study

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Abstract

Background: The body of empirical research is suggestive of the fact that faster walking speed and increasing heel height can both give rise to elevated plantar pressures. However, there is little evidence of the interaction between walking speed and heel height on changes in plantar pressure. Therefore, the aim of this study was to investigate whether the effect of heel height on plantar pressure is the same for different walking speeds

Methodology: Eighteen healthy adults, between the ages of 18 and 35 were assessed for changes in peak plantar pressure at walking speeds of 0.5 mph, 0.8 mph, 1.4 mph and 2.4 mph on a treadmill, wearing heels of 2 cm, 3 cm, 6 cm and 9 cm. Both the speed of walking and heels were randomly assigned to each participant. Peak plantar pressure values were determined in the forefoot region using the F-scan system which made use of in-shoe insoles. Data were analysed using two-way ANOVA.

Results: Increasing heel height and walking speed resulted in significantly higher peak plantar pressure in the forefoot. Post-hoc analysis also confirmed the findings of two-way ANOVA of significant increase in peak plantar pressure with increments in heel height and walking speed. The two-way ANOVA illustrated significantly higher peak plantar pressures in both the forefeet due to interaction of walking speed and increasing heel heights.

Conclusion: This study suggests that an interaction of walking speed and footwear design on distribution of plantar pressure exists. Therefore it is necessary to standardize walking speed and shoe design in future studies evaluating plantar pressures.

Keywords: Plantar pressure; Walking speed; Heeled shoes; Pressure distribution; Forefoot

Fashionable footwear designs are now becoming increasingly complex and incorporating high heels; some designs include heels up to 10 cm or more [1]. Footwear purchase is dictated by fashion and not a sense of comfort [2]. It has been reported that 49% of American women own high heeled shoes, of which 71% reported foot pain [3]. High heeled shoes have come under much speculation as one of the causative factors for forefoot pain and discomfort. Literature relating to effects of high heels offer conflicting findings.

Dawson et al. [4] reported foot problems such as great toe deformity, foot pain, cross fingers and arthritis affecting the feet in 83% of women using high heeled shoes. A study in Netherlands found that 60% of women and 30% of men suffered similar foot problems directly related to shoes [5]. However, a recent study reported that wearing high heels did not cause deformities in women, but pain and callosities [6]. A recent review identified that musculoskeletal problems including hallux valgus, pain and first-party injury were associated with high heeled shoes [7].

The biomechanical effects of high heel shoes ranging from 2 cm up to 10 cm have been studied by various researchers in the past [1,8-12]. In terms of measurement, the peak plantar pressure is defined as the highest pressure value recorded by each sensor over the entire period of the stance phase [13]. Elevated peak plantar pressures are of significant concern due to risk of tissue injury, foot discomfort, a source of pain, foot ulceration and arthritic changes in the foot [14]. It has been reported that high heeled shoes directly affect biomechanics of gait, including the peak plantar pressure distribution. There is an increase in peak plantar pressure under the forefoot as a result of realignment of body segment such that center of pressure shifts further anteriorly and medially [9,10,15-17]. Speksnijder and colleagues report an increase of 30% in peak plantar pressure under the forefoot region in women wearing high heels [11].

Similarly, other studies reported increase in forefoot peak pressures with increase in heel height [18,19]. Walking speed is another important variable that influences plantar pressure. Studies have reported that an increase in walking speed results in higher plantar pressures [20-22]. This has been supported by the evidence that suggests that there are higher vertical ground reaction forces with faster walking speeds [23] as force is directly proportional to pressure (Pressure=Force × Area^{-1}). Warren and colleagues, using a sample of

19 men, repo⅜ rṅ

speed and heel height was approximately 12 steps for each foot (6 gait cycles). The recording was generated throughout the 6 gait cycles and the middle 3 steps were used to extrapolate peak plantar pressure measurements generated during the entire stance phase. The 3 selected recordings were then averaged for each foot.

Peak plantar pressure (KPa) was measured in the forefoot region. The forefoot was considered the metatarsal heads and toes [27]. For the analysis, a mask encompassing the forefoot region was defined in the F-scan software version 6.30. Peak plantar pressure values and its distribution were extracted from this mask (forefoot region).

A Shapiro-Wilks test was carried out and data was normally distributed ($p>0.05$) hence a two-way Analysis of Variance (repeated measures) was carried out. This was followed by post-hoc pair wise comparisons using paired t-tests with applied Bonferroni corrections, to compare between

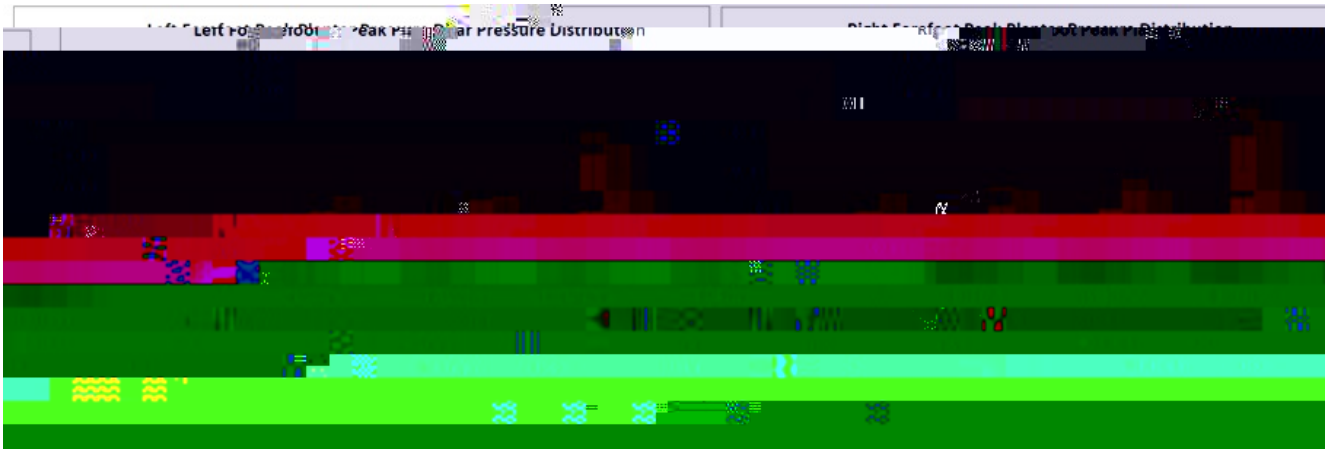

Figure 2: Illustrates peak plantar pressure across the le f

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