Introduction

Background
- Foot and gait pathologies may be identified by aberrant plantar pressure distribution during gait. Foot pressure distribution is typically measured in clinics and gait labs using relatively short walkway or a treadmill. It is unknown how well those clinic-based or laboratory-based measurements of plantar pressure reflect “real world” foot loading that occurs outside the lab.
- One factor known to affect plantar pressure during gait is foot type (planus, normal, cavus). However, it is not clear if foot type differences in plantar pressure are consistent across different walking surfaces.

Aim
- To investigate the effects of foot type on plantar forces (PF) during walking on four different surfaces (lab walkway, grass, outdoor pavement and treadmill).

Hypotheses
- Participants with planus feet would have higher midfoot plantar forces over all walking surfaces.
- The plantar forces would be greater when walking on pavement in comparison to treadmill, grass and laboratory walkway.

Methods

Data Collection
- 94 healthy adults (Table 1) with no history of injury or surgery in two age groups, young (20-35 years old) and old (55-70 years old), were enrolled with IRB approval and informed consent. The study included in this study.
- All participants wore the same type of shoes (Nike Zoom) and walked at a self-selected pace for at least 5 minutes on four different surfaces: treadmill (TM), 7.8 m laboratory walkway (LW), 80 m outdoor pavement (PM), and 30 m grass (GS) in a random order.
- A Pedar insole pressure system (Novel Electronics Inc) collected bilateral plantar pressure at 100 Hz using 99 sensors.

Data Processing
- Overall plantar force during each foot strike was calculated from the pressure recordings and the foot regions’ area. They were then normalized to body weight.
- The first peak force (P1: weight acceptance) and the second peak force (P2: push-off) were identified for each step. (Figure 1)
- The sensors were partitioned into 9 regions. (Figure 2)
- The Peak Regional Force (PRF), defined as the peak force within each region, was calculated for each step. These values were averaged over all steps for each surface for each participant.
- The Arch Index (AI), determined from footprints, was used to classify foot type as planus<0.28 (low arch), 0.21<normal<0.28 and cavus<0.21 (high arch)).

Data Analysis
- A 2-way repeated measures ANOVA (Walking surface x Foot type) was performed to identify differences among walking surfaces and foot types for P1 and P2, and for PRF within each foot region, significance was set at p<0.05. The Bonferroni correction was applied for multiple comparisons.

Table 1. Demographic data. F = female, M = male, Y = young, and O = old.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>This Study</th>
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<tbody>
<tr>
<td>Subjects (F/M)</td>
<td>94 (52/42)</td>
<td>70 (41/29)</td>
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<tr>
<td>Age (YO)</td>
<td>43±1.85 (50/44)</td>
<td>43.9±1.82 (37/33)</td>
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<td>BMI (kg/m²)</td>
<td>25.0±3.1</td>
<td>24.9±3.2</td>
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Results

- There were 43 planus, 57 normal and 40 cavus feet analyzed. An average of 140 steps per foot from each surface were included.
- The Effects of Foot Type:
  - Foot type did not affect P1 and P2 (p>0.056). PRF in the heel (F1 & F2) was greatest in cavus and smallest in planus feet (p<0.002). (Figure 3A), confirming the findings of Morag et al.
  - Midfoot PRF (F3 & F4) was greatest in planus and smallest in cavus feet (p<0.044). (Figure 3B).
  - Forefoot PRF (F5 & F6) was greatest in cavus and smallest in planus feet (p<0.031). (Figure 3C).
- No differences in toe PRF (F8 & F9) were observed among foot types.
- The Effects of Walking Surface:
  - P1 and P2 were significantly higher during OP and GS than during TM and LW (p<0.01).
  - Differences were most apparent in the heel (F1 & F2), with all PRFs decreasing from OP to GS to LW to TM (p<0.001).
  - Midfoot PRF was greater during OP than other surfaces (p<0.024).
  - Forefoot and toe (F5 to F9) PRFs were lower during TM walking in comparison to other surfaces (p<0.003).
- Interaction Between Foot Type and Walking Surface:
  - Significant interactions were found between foot type and walking surface in foot regions F2, F3, F4, and F7 (p<0.04).

Discussion

- The results support our first hypothesis that planus feet would have higher plantar forces in the midfoot area in comparison to normal and cavus feet, and also the second hypothesis that plantar forces were greater during OP walking in comparison to GS, LW and TM.
- Strengths include a relatively large sample size, number of analyzed steps and different walking surfaces. The primary limitation is that the effects of walking speed on PF were not investigated.

Clinical Significance
- Plantar forces measured in a controlled environment appear to underestimate peak forces experienced during outdoor walking.
- Laboratory or clinical evaluation may therefore fail to identify some potentially harmful loads on the feet.
- Foot type significantly affects PRFs and must be considered during any assessment of regional foot loading.
- Significant interactions within the midfoot suggest that the mechanical response of the arch dependent upon foot types and walking surfaces.

References and Acknowledgements


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