The Influence of Orthotic Forefoot Lifts on Plantar Foot Pressures During Double Limb Stance

Keven Dunn, BSME
Géza F. Kogler, Ph.D., C.O.
Clinical Biomechanics Laboratory
Georgia Institute of Technology
Introduction

- Foot pain due to prolonged standing is common in several professions such as:
  (Messing 2001)
  - Hairdressers
  - Teachers
  - Food preparation staff
  - Factory workers
Common treatment modalities include:

- Wedges
- Lifts
- Metatarsal Pads
- Arch Supports
Introduction

- Study focused on the use of a **forefoot lift** (metatarsal head and corresponding phalanges) as the **orthotic control mechanism**.
Key terms

- MTH(s)- Metatarsal Head(s)
- Plantar Pressure – are maximum mean pressures
- Maximum mean pressure - the largest mean pressure measured in each mask for all steps in a trial
Purpose

- Quantify **plantar pressure re-distributions** during quasi-static double limb stance using various **forefoot lifts** (i.e. metatarsals and phalanges)

- To determine the importance of orthotic **forefoot lift height** on **plantar pressure redistribution**
Hypotheses

- **Plantar pressures will increase** at the forefoot lift contact area compared to the non-forefoot lift condition (control).

- An **increase** in forefoot lift height will **increase plantar pressures** at the point of contact with the lift.
25 subjects
9 males and 16 females
Asymptomatic feet
Evaluated
  - Using medical history questionnaire
    - Foot pathologies
    - Neuromusculoskeletal disorders
    - Surgeries of the foot/ankle complex
  - Foot Posture Index (FPI) (Redman et al. 2006)
    - Subjects included if: -6 ≤ FPI ≤ 6
**Methods**

<table>
<thead>
<tr>
<th>General descriptive parameters of subjects (n =25)</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td>19</td>
<td>74</td>
<td>37</td>
<td>17</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>157.50</td>
<td>188.00</td>
<td>170.1</td>
<td>8.8</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>56.40</td>
<td>116.40</td>
<td>72.6</td>
<td>14.9</td>
</tr>
<tr>
<td><strong>BMI (kg/m^2)</strong></td>
<td>18.0</td>
<td>41.0</td>
<td>25.2</td>
<td>5.3</td>
</tr>
<tr>
<td><strong>Foot Posture Index Left</strong></td>
<td>0</td>
<td>5</td>
<td>1.96</td>
<td>1.70</td>
</tr>
<tr>
<td><strong>Foot Posture Index Right</strong></td>
<td>0</td>
<td>5</td>
<td>2.40</td>
<td>1.60</td>
</tr>
</tbody>
</table>
Pedar pressure distribution insoles
(Novel GmbH, Munich, Germany)

- 99 sensors in each insole
- 6 insole sizes
- Data sampled at 50 Hz per a sensor
Methods: Custom Standing Frame

- Methods incorporated to reduce postural sway
  - Fingertip touch (Jeka 1997)
  - Subjects looked at a fixed image at eye level to reduce postural sway (Vuillerme 2006)
Methods

- Custom standing frame
  - Repeatable standing posture frame locks to subject alignment
  - Adjusts for Toe-out angle
  - Stance width
  - Adjusts for fingertip height and depth
Methods

- Conditions each at a height of 4, 8, 12 mm

Control 1st MTH 1st–2nd MTHs

2nd–5th MTHs 3rd–5th MTHs
Data Analysis

- Foot divided into 10 regions
  - 1\textsuperscript{st} toe, 2\textsuperscript{nd} toe, 3\textsuperscript{rd}-5\textsuperscript{th} toes
  - 1\textsuperscript{st} MTH, 2\textsuperscript{nd} MTH, 3\textsuperscript{rd}-5\textsuperscript{th} MTH
  - Medial and Lateral midfoot
  - Medial and Lateral heel
- This mask configuration was adopted from research conducted by Cavanagh et al. 1987
Data Analysis

(Cavanagh et al., 1987)
Data Analysis

- Pressure significant differences were calculated using a single factor repeated measures ANOVA
- Significance calculated at $p < 0.05$
Both left and right follow the same trend but have different magnitude of change.
Both left and right follow the same trend but have different magnitude of change
Both left and right follow the same trend but have different magnitude of change.

Max Mean Pressure (kPa)

Left vs. Right 3rd - 5th MTH
1st MTH forefoot lift increase pressure at 1st MTH
3rd-5th MTH forefoot lift decrease pressure at 1st MTH

Mean difference is significantly different (p < 0.05) from:
* Control * 4mm * 8mm * 12mm condition
1\textsuperscript{st} – 2\textsuperscript{nd} MTH forefoot lift no change in pressure at 1\textsuperscript{st} MTH
1\textsuperscript{st} – 2\textsuperscript{nd} MTH forefoot lift increases pressure at 2\textsuperscript{nd} MTH

Mean difference is significantly different (p < 0.05) from:
* Control * 4mm * 8mm * 12mm condition
1st MTH forefoot lift decreases pressure at 3rd – 5th MTH
3rd-5th MTH forefoot lift increases pressure at 3rd – 5th MTH

Mean difference is significantly different (p < 0.05 ) from:
* Control * 4mm * 8mm * 12mm condition
The hypothesis: **Plantar pressures will increase** at the forefoot lift contact area compared to the non-forefoot lift condition (control).

- Partially Confirmed
  - **Confirmed** for 1<sup>st</sup> MTH forefoot lift condition
  - **Confirmed** for 3<sup>rd</sup> – 5<sup>th</sup> MTH forefoot lift condition
  - **Not confirmed** for 1<sup>st</sup>- 2<sup>nd</sup> MTH forefoot lift condition
1\textsuperscript{st} – 2\textsuperscript{nd} MTH forefoot lift no change in pressure at 1\textsuperscript{st} MTH
1\textsuperscript{st} – 2\textsuperscript{nd} MTH forefoot lift increases pressure at 2\textsuperscript{nd} MTH

Mean difference is significantly different (p < 0.05) from:
* Control
* 4mm
* 8mm
* 12mm condition
Hypothesis 1: not confirmed for 1st-2nd MTH forefoot lift condition

- Pressure **increased** at the 2nd MTH
- Pressure did **not increase** at 1st MTH
  - Pressure images show an increase in plantar pressures occurring at the **medial side** of the lift
An **increase** in forefoot lift height will **increase plantar pressures** at the point of contact with the lift.

- Partially confirmed
  - **Confirmed** for 1st MTH forefoot lift condition
  - **Not Confirmed** for 1st – 2nd MTH forefoot lift condition
  - **Not confirmed** for 3rd – 5th MTH forefoot lift condition
1\textsuperscript{st} MTH forefoot lift decreases pressure at 3\textsuperscript{rd} – 5\textsuperscript{th} MTH.
3\textsuperscript{rd}-5\textsuperscript{th} MTH forefoot lift increases pressure at 3\textsuperscript{rd} – 5\textsuperscript{th} MTH.

Mean difference is significantly different ($p < 0.05$) from:

* Control
* 4mm
* 8mm
* 12mm condition
Hypothesis 2: not confirmed for 3rd – 5th MTH forefoot lift condition

- More than 50% of subjects had a **lower pressure** at the 3rd – 5th MTHs for the 12mm height compared to the 8mm height
  - Forefoot lift may have extended to far into midfoot
  - Pressure moved to lateral midfoot and heel
Discussion

- Left and right foot were **not** significantly correlated

**Literature Review**

- Other studies primarily *walking studies* have correlations between left and right foot (Van Gheluwe 2004) (Guldemond 2008) (Kanatli 2008)

- A *standing study* by Cavanagh et al. 1987 also had asymmetries between the left and right foot that could not be explained.
Limitations

- **Foot Structure**
  - Foot structure **stiffness** may be a factor
  - Leg length **asymmetry** may be a factor

- **Standing Posture**
  - Postural standing studies are challenging due to the difficulty to control postural sway
  - For example: heart rate and respiration both influence postural sway (Takata 1983)
Conclusions: Orthotic elevations of the 1\textsuperscript{st} MTH and Phalanges

- **Increases** pressure at 1\textsuperscript{st} MTH (4, 8, 12mm)

- **Decreases** pressure at 3\textsuperscript{rd} - 5\textsuperscript{th} MTH (4, 8, 12mm)
Conclusions: Orthotic elevations of the 1\textsuperscript{st} – 2\textsuperscript{nd} MTHs and Phalanges

- Does not significantly change pressure at 1\textsuperscript{st} MTH or 3\textsuperscript{rd} – 5\textsuperscript{th} MTH

- Increases pressure at 2\textsuperscript{nd} MTH
Conclusions: Orthotic elevations of the 3\textsuperscript{rd} – 5\textsuperscript{th} MTHs and Phalanges

- **Decreases** pressure at 1\textsuperscript{st} MTH for 4, 8, 12mm

- **Increases** pressure at 3\textsuperscript{rd} – 5\textsuperscript{th} MTH 4, 8, 12mm
Clinical Application

- Factory worker
  - Presents with foot pain in lateral forefoot
  - Metatarsalgia of the 5th MTH
  - Prolonged standing and loading
  - Standing only foot orthosis

<table>
<thead>
<tr>
<th>Where is the pressure reduction needed?</th>
<th>Recommended orthotic forefoot lift</th>
<th>Orthotic forefoot lift height</th>
<th>Resultant percent decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Metatarsal Head</td>
<td>3rd-5th MTHs Forefoot Elevation</td>
<td>4 mm</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 mm</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 mm</td>
<td>62%</td>
</tr>
<tr>
<td>3rd-5th Metatarsal Heads</td>
<td>1st MTH Forefoot Elevation</td>
<td>4 mm</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 mm</td>
<td>16%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 mm</td>
<td>24%</td>
</tr>
</tbody>
</table>
References


Acknowledgements

- Géza F. Kogler, Ph.D., C.O.
  - Research advisor
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  - Research partner and Excel extraordinaire
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  - For the many statistics questions answered
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  - Fellow students, AP faculty, family, and friends

Thank You!
Questions?

- Dale the following slides were to be included if there was a question on them.
Future Research

- Leg length asymmetries influence on double limb stance plantar pressures
- Foot stiffness characteristics
- Pathological foot types
Age, Gender, BMI, and Foot Posture Index were not significantly correlated

- BMI/Weight  (Cavanagh 1987) (Kanatli 2008)
- Gender   (Cavanagh 1987) (Kanatli 2008)