The Influence of Orthotic Forefoot Lifts on Plantar Foot Pressures During Treadmill Walking

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Introduction to Foot Orthoses

- Foot pain is very common
  - Reports range of prevalence from 14% to 83% (Benvenuti et al 1995, Postema et al 1998, Spahn et al 2004)
  - Most common area is forefoot (Adelaide Health Study 2007)
- Metatarsal pads and custom foot orthoses are commonly prescribed to reduce plantar pressure (Mueller et al 2006)
  - Custom inserts seek to evenly distribute pressure over the entire plantar surface
  - Metatarsal pads serve to provide additional forefoot pressure relief
- Other inserts can be used to decrease pressure in specific areas all together or to control motion in the foot complex
  - Ex. Morton's extension
References:  
A. http://www.prolaborthotics.com/LinkClick.aspx?fileticket=NMNQDqA0F3U%3d&tabid=85  
C. http://www.prolaborthotics.com/LinkClick.aspx?fileticket=KN8R7CkajoQ%3d&tabid=85  
Foot Problems

• The following are pathologies that could require unloading of an area of the forefoot
  – Plantarflexed first ray
  – Hallux limitis
  – Sesamoiditis
  – Severe forefoot valgus deformity
  – Dorsiflexed first ray
  – Turf toe

http://www.theorthoticgroup.com/TOG-Professionals-Additions.html

Image: http://rothbartsfoot.info/PF1stMetPhotos.html
A need for biomechanical measures to assist in prescription formulation.

For example: percent change% -- Pressure

- Majority of foot orthoses practices are based on subjective experience rather than evidence based studies
- Plantar pressure studies can be used as an outcome measure for evidence based research
Hypothesis

• Plantar **foot pressure patterns** during walking are **altered** with orthoses that incorporate partial or full **forefoot** elevations.
Subjects

- **23 Subjects total**
- 10 Males, 13 Females
- **Age:** 19-74 (Mean: 37 years)
- **BMI:** 18.61 – 39.31 (Mean: 25.65)
- **Foot Posture Index** (Redman et al., 2006) looks at standing foot posture
  - Subjects excluded from study if found to have abnormal foot posture
Equipment

• Pedar pressure distribution insoles (Novel GmbH, Munich, Germany) placed inside shoes on top of insole, to measure pressure distribution
Test Conditions (Right Foot)

- Control
- 1st
- 1st – 2nd
- 1st – 3rd
- 1st – 4th
- 1st – 5th
- 4mm & 8mm
- 1st – 5th
- 2nd – 5th
- 3rd – 5th
- 4th – 5th
- 5th
Testing Procedure

- One of 11 insole configurations were put into a flat sole shoe
- Pedar pressure insoles which matched the shoe size were added in the shoe
- Subject walked on treadmill at 3 velocities
  - (1.0 m/s, 1.2 m/s, 1.5 m/s)
- Pressures recorded once subject was comfortable at the walking speed
- Procedure was repeated for all 11 insoles
- The order of the conditions and velocities were randomized
Statistical Analysis

• Data for maximum mean pressure (MMP) analyzed using SPSS
  – Analyzed middle velocity (1.2 m/s)
• T-Test to compare right and left feet
• Single factor univariate repeated measure ANOVA
  – Bonferroni Post Hoc analysis
  – Significant if p < 0.05
Right and Left Feet are Different

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<tr>
<th>Pair</th>
<th>Significance</th>
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<tr>
<td>TotalL - TotalR</td>
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<tr>
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<td>Left Lat Heel – Right Lat Heel</td>
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(p < 0.05)
1<sup>st</sup> Metatarsal

R = Right Foot
L = Left Foot

= Forefoot Elevation

(p < 0.05)
2\textsuperscript{nd} Metatarsal

R = Right Foot
L = Left Foot

= Forefoot Elevation

(p < 0.05)
3rd Metatarsal

R = Right Foot
L = Left Foot
= Forefoot Elevation

(p < 0.05)
4th & 5th Metatarsals

R = Right Foot
L = Left Foot
= Forefoot Elevation

(p < 0.05)
1st Toe

Pressure

Control  3rd – 5th Raised
Pressure Distribution Pattern at 1st Toe

% Change from Control

Increase

(p < 0.05)
Medial Heel

1st – 5th Raised

Pressure

Control
Pressure Distribution Pattern at Medial Heel

% Change from Control

Increase

(p < 0.05)
Discussion

• The results support the hypothesis
  – Full/partial forefoot elevations redistribute pressures in the plantar surface of the foot
Key Findings

1. 1st toe appeared to be an important factor in pressure redistribution

   – Often notes an increase in MMP
     • 9/10 conditions on the left foot and 8/10 on the right foot
   
   • From the Literature:
     – Morton’s extension insert increased MMP on great toe Morris et al 2009
     – Greater peak pressures under great toe vs. metatarsal for people with hallux limitus Van Gheluwe et al 2006

   • Implication:
     – Chance that altering pressures in the metatarsal heads will increase pressure at the first toe
     – If the patient has a first toe that is susceptible to breakdown, this may be a concern; other orthoses should be utilized

Image: http://www.kevinorthotics.com/images/morton_s_extension_pad.png
Key Findings

2. Orthotic elevation of the 1st metatarsal and phalanges caused increased MMP at the **medial heel**
   - Increases in MMP for conditions 1, 1-2, 1-3, 1-4, 1-5 (4 & 8mm)
   - Medial attachment of plantar fascia at medial calcaneal tubercle  Fuller 2000
   - Raising/adding force to 1st metatarsal phalanges increases medial pull of plantar fascia  Fuller 2000
     - Causes shortening the foot and increased pressure at medial heel
   - **From the Literature:**
     - Medial forefoot wedge resulted in increased strain of plantar aponeurosis  Kogler et al 1999
     - No difference found in heel pressure with varus/valgus wedging of forefoot  Van Gheluwe et al 2004

![Image from Fuller 2000](image)
Key Findings

3. In general, pressure redistribution will occur with orthotic elevations to the forefoot (*intuitive*).

- To decrease pressure at 1\textsuperscript{st} Metatarsal:
  - Elevate the 2\textsuperscript{nd} -5\textsuperscript{th} or 3\textsuperscript{rd} -5\textsuperscript{th} regions of the forefoot
  - Causes increases in MMP in 2\textsuperscript{nd} -4\textsuperscript{th} metatarsals and 1\textsuperscript{st} Toe
  - No changes in the heel

- *From the Literature:*
  - Orthotic interventions in other areas contribute to pressure redistribution, for example, metatarsal pads and wedges.
  - Metatarsal supports decreased force under 2\textsuperscript{nd} metatarsal head and toes when positioned 5-25mm proximal to the metatarsals \textsuperscript{1}Brodtkorb et al 2007
    - Increased force at area of metatarsal support and at midfoot
  - Increased varus wedging increases peak pressure in medial forefoot and rearfoot
    - Valgus wedging increases lateral forefoot and rearfoot peak pressure \textsuperscript{2}Van Gheluwe et al 2006
Limitations

• Forefoot lifts extended into the midfoot.
  • Not able to analyze pressures in the midfoot

• Limited number of sizes of pressure insoles.
  • Insole did not always completely cover the entire test insole
  • Migration/movement of insole in shoe possible

• Did not look at subject’s foot dominance
  • May tend to put more weight on more dominant foot
Conclusions

• In general, orthotic forefoot lifts altered pressure patterns of the foot
  – Specifically, these are the areas we observed:
    1. Majority of forefoot lifts resulted in an increased pressure at the first toe
    2. Raising the first metatarsal and phalanges resulted in increased pressure at the medial heel
    3. Orthotic elevations of the forefoot will result in pressure redistribution
Clinical Relevance

• How a clinician can use this data.
  - Clinicians can predict where pressures may increase with a given orthotic elevation to the forefoot.
  - For example:
    - If a patient is susceptible to breakdown in the medial heel
      » Don't want to raise 1st metatarsal and phalanges
    - Patient presents with inflammation of 1st metatarsal due to plantarflexed first ray
      » Want to decrease pressure on the 1st metatarsal
      » Elevate 2nd – 5th or 3rd – 5th
Acknowledgements

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References


Questions?