The Influence of Negative Heels on Plantar Foot Pressures during Treadmill Walking

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Introduction:

• Plantar foot pressures reflect general loading patterns of the foot (Cavanagh et. al. 1992)

• Deviation from a flat surface
  – yields a different pressure pattern
  – therapeutic value
Purpose

• To evaluate the influence of a negative heel on plantar foot pressures during walking in healthy subjects

• Observe the mechanics of how the foot responds with regard to loading
Pressures Measurements

• Factors play a role in plantar pressures (Burnfield et al 2003)
  – velocity
  – footwear

• Pressure is important when evaluating the effect a device (Neumann 2002)
Hypothesis

• A **negative heel** on a shoe’s sole will **decrease** forefoot plantar pressures and **increase** rearfoot (heel) **plantar pressures** during treadmill walking.
Foot Structure & Function

- **3 sections** (Neumann 2002)
  - **Rearfoot** – absorbs and transfers large loads
  - **Midfoot** – transfers loads and helps to lock/unlock the foot
  - **Forefoot** – leverage & balance
- Metatarsal heads (MTH)
The Negative Heel

• Negative heel position: the heel lower than forefoot when entire foot is on the ground
• Negative Heel = a wedge
  – elevates the entire forefoot
The High Heel

• **Increased pressures at the forefoot** - correlates with heel height (Witana et al. 2009, Ramanathan et al. 2008)
  – Logically a negative heel opposite effect?

• **Plausible issues**
  – Foot not designed to fully weight bear on forefoot
  – Western culture - shod society (shoe) that elevates the heel
Why a “Negative Heel”

• An increased popularity that claims “fitness” benefit
  – No evidence of effect on plantar pressures
  – Address the basic mechanics & loading

• One popular brand states a 3.7° negative heel wedge
Methods:

- **Subjects:**
  - 10 asymptomatic healthy volunteer subjects
    - 6 Female, 4 male
    - Each took survey, having no known neurological or orthopedic pathology = healthy
  - Ages: 19 to 27 years (mean = 23)
  - Capable of walking on a treadmill unaided
  - Ankle range of motion fell within normal limits while knee extended according to AAOS standards
Methods

- 3 conditions
  - Control (flat with no wedge)
  - 2° inclined wedge
  - 4° inclined wedge

- Velocity
  - 1.3 m/s
    - Average self selected walking speed adults (Perry, 1992)

- Order of conditions were randomized

- Approved IRB
Plantar Measurement Tools
Materials

• Negative heel wedges:
  – Standard shoe soling material (SoleTech Salem MA)
  – Material properties- hardness (Shore A Durometer of 70 to 75) (i.e., firm)
Analysis Method:

• Peak pressures averaged over range of 8 to 10 steps per subject
  – Only 3 or more steps required to establish reliable peak pressures (Hughes 1991)

• Compared all subjects across conditions and each region of the foot
Data Analysis:

- 9 regions (Cavanagh 1992)
- Repeated measures ANOVA was performed in SPSS
  - Compared differences across all conditions
- Boneferroni Post-hoc
  - Significance p-value ≤ 0.05
Results
Mid-Forefoot (2-3 MTHs)

* $p \leq 0.05$
Results
Lateral Toes

* $p \leq 0.05$
Results
Lateral Forefoot (4-5 MTHs)

* No significance
Discussion

• A **negative heel** on a shoe’s sole will **decrease** forefoot **plantar pressure** and **increase** rearfoot (heel) **plantar pressures** during treadmill walking.

  — Partially supported
  — Peak pressures decreased at the forefoot (MTH 2-3) \( p \leq 0.05 \)
  — **Peak pressures at the heel were not significantly changed compared to the control**
Discussion

- **Peak Pressures on Forefoot decreased** – forefoot loading pattern changed ($p < 0.05$)
- The medial and lateral heel appear to bear a greater portion of the load compared to the control (no forefoot elevation)
- Pressure pattern adopts a **Posterior Shift** in plantar foot loading with regard to peak pressures
Discussion

• When the foot interacts with a negative heel interface, the loads shift from
  - mid forefoot, 2-3 MTH significantly (p < 0.05)
  - Lateral toes significantly (p < 0.05)
  - Lateral forefoot (lesser degree) 4-5 MTH
Discussion

• Polymodus Support – Multiple Load Transmission Strategies
  – The load transmission path of the foot will modulate as it adapts to a surface change through the use of different structural support mechanisms (Kogler et al., 1999)
• Polymodus support
  – The mode that appears to be adopted is one that shifts loads away from the lateral MTH and increases loading to the heel
  – Results from this study support that theory
Discussion

• This study demonstrates the considerable differences in load redistribution on the plantar surface based on the design of the sole of the shoe.

• This observation is also noted by other investigators who have shown that with elevation of the heel (i.e., high heeled shoes), where pressure increased at forefoot (Mandato & Nester, 1999).
Conclusion

• A negative heel results in a decrease in peak pressures at the 2nd - 3rd MTH and lateral toes compared to a planar level surface without a negative heel during treadmill walking.
Clinical Relevance

• Notable decreases in PP at the 2-3 MTH with a negative heel may be of value when targeted pressure redistribution is a clinical objective

• Examples:
  – Relieve foot pain (e.g., metatarsalgia)

• This information may be important to (Janisse & Janisse 2008):
  – orthotic prescription formulation
  – shoe recommendations
Limitations & Future Studies:

• Only evaluated healthy, relatively young adults
  – future research should look at populations of different ages and those with different foot pathologies

• Structural stiffness of the foot was not controlled

• Kinematic and muscle activity measures (EMG) – other metrics to collect
Take Home Message

• The foot responds mechanically when the shoe is altered which can be evaluated quantitatively by plantar pressures
  – A negative heel may aid in reducing overall forefoot pressure
• Hopefully you have another “nugget” of knowledge to add to your clinical toolbox
References:

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QUESTIONS??
Conditions
• Results are consistent in the literature that load bearing (PP) shift towards the heel when the forefoot is elevated with a rocker bottom type intervention (Praet and Louwerens 2003)
• Static loading on forefoot increases with increasing heel height (Snow and Williams 1994 & Witana et al. 2009)
• A study by Witana et al 2009 found that pressures
  – not exceeding 255 kPa no pain clinically
  – Assuming pain pressure thresholds from the hand