GLUTEUS MEDIUS, RECTUS FEMORIS, PERONEUS LONGUS AND MEDIAL GASTROCNEMIUS ACTIVATION IS INFLUENCED BY FOOTWEAR AND ACTIVITY

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SUMMARY
The purpose of this study was to assess the effect of footwear (low versus high heels) and activity (walking versus step down) on activation of the gluteus medius, rectus femoris, peroneus longus and medial gastrocnemius muscles. Electromyography (EMG) data were collected on fourteen subjects wearing standardized lab issued high and low heeled shoes, during walking and a step down task. EMG data were acquired using surface electrodes at 1200 Hz. Linear envelopes were created, and EMG amplitude was expressed as a percentage of peak activation noted during walking with low heel shoes. The effect of activity and footwear on peak muscle activation was examined using a two-way repeated measures ANOVA.

A significant simple effect of footwear was noted during walking ($P<0.001$) and step down ($P=0.025$) for peak activation of the peroneus longus. Significant main effects of activity were noted for the gluteus medius ($P=0.004$), rectus femoris ($P=0.001$) and medial gastrocnemius ($P=0.034$) muscles. Significant main effects of footwear were noted for the rectus femoris ($P=0.003$) and medial gastrocnemius ($P=0.005$) muscles. Similar trends were noted for the gluteus medius ($P=0.08$). The findings of our study support the contention that muscle activation is influenced by both, heel height as well as activity.

INTRODUCTION
Population based studies indicate that high heeled shoes (2 inches / 5 cm or higher) are worn by 57-62% of women, and that the use of high heeled shoes may contribute to the development of foot pain and degenerative changes [1]. High heeled shoes may contribute to the development of foot pain by adversely affecting joint kinematics, muscle activation and consequent joint loading [2]. In particular, high heeled shoes may place increased demands on lower extremity musculature, reflected as increased activation. While previous studies have assessed the effects of high heeled shoe use on muscles such as the gastrocnemius and rectus femoris, limited data are available related to the peroneus longus and gluteus medius. Recent reports indicate that the latter two muscles may play an important role in sagittal as well as frontal plane function at the ankle, knee and hip joints [3].

In addition to heel height, lower extremity muscle activation may be influenced by the activity being performed. While most studies have assessed lower extremity muscle activation during level walking, few studies have assessed more challenging non-gait activities such as a single limb step descent. Step descent may mimic the demands placed during activities of daily living such as stair descent or stepping off a curb. The purpose of this study was to assess the effect of footwear (low versus high heels) and activity (walking versus step down) on activation of the gluteus medius, rectus femoris, peroneus longus and medial gastrocnemius muscles.

METHODS
All study procedures were approved by the IRB. Fourteen female subjects who were screened for lower extremity pain or dysfunction, and were not regular users of high heeled shoes participated in this study. They performed two activities, walking and step down, wearing standardized, lab-issued low heeled (0.75 inch / 1.91 cm) and high heeled (3 inches / 7.62 cm) shoes (DSW Columbus, OH), sized to their feet. All walking was performed along a 15 foot walkway, the step down was performed over an 8 inch / 20.32 cm custom-built step. Subjects were allowed as many practice trials as they needed to feel comfortable with the footwear and step. A minimum of five trials were collected for each activity and footwear condition as the subjects walked at self-selected walking speed, monitored to ±5% using an infra-red timing device (Polaris Farmtek, NC). Ground reaction force data, collected at 1200 Hz using a forceplate, was used to define the duration of stance phase.

Electromyography (EMG) data were collected over the gluteus medius, rectus femoris, peroneus longus and medial gastrocnemius muscles using bipolar surface electrodes (Bagnoli-8, Delsys, Inc., Boston MA, USA). A single tester (RR) prepared the subjects’ skin by cleaning with alcohol and gentle abrasion, and placed EMG electrodes (DE2.1 Bagnoli, Single Differential Parallel Bar, 10 mm Contact Spacing). Data were collected at 1200 Hz, CMRR=92 dB, Gain=1000. The ground electrode was affixed over the spine of the C7 vertebra. All EMG electrodes and wires were secured using skin adhesive interface tape and pre-wrap.

Linear envelopes of EMG data were created by band-pass filtering (2nd order, zero-lag, Butterworth filter, with cutoff frequencies of 20 and 300 Hz), full-wave rectifying and low-pass filtering (2nd order, zero-lag, Butterworth filter, with cutoff frequency of 7 Hz) raw EMG data. Muscle activation was quantified as EMG amplitude, expressed as a percentage of peak activation noted during walking with low heel shoes. All EMG data were time-normalized to the stance phase.
Peak muscle activation in the stance phase was calculated for each muscle during each activity and footwear condition, and served as the chief dependent variable of interest. The effect of activity and footwear on peak muscle activation was examined using a two-way repeated measures ANOVA (IBM SPSS 19). Interaction effects were assessed first, followed by simple or main effects as appropriate ($\alpha=0.05$).

**RESULTS AND DISCUSSION**

A significant interaction effect (footwear x activity) was noted for peak activation of the peroneus longus ($P=0.025$). Subsequently, the effect of footwear was assessed for each activity (simple effect). A significant simple effect of footwear was noted during walking ($P<0.001$) and step down ($P=0.025$) activities.

No interaction effects were noted for peak activation of the gluteus medius ($P=0.10$), rectus femoris ($P=0.689$) or medial gastrocnemius ($P=0.985$) muscles. Subsequently, significant main effects of activity were noted for peak activation of the gluteus medius ($P=0.004$), rectus femoris ($P=0.001$) and medial gastrocnemius ($P=0.034$) muscles. Significant main effects of footwear were noted for peak activation of the rectus femoris ($P=0.003$) and medial gastrocnemius ($P=0.005$) muscles. Similar trends were noted for peak activation of the gluteus medius ($P=0.08$).

**CONCLUSIONS**

The key findings of our study indicate that muscle activation is influenced by both, heel height as well as activity. Overall, the use of high heel shoes during walking resulted in increased activation in the medial gastrocnemius (29%), peroneus longus (80%), rectus femoris (160%) and gluteus medius (11%). Similar increases were also noted during the step down activity (41, 21, 77, and 45% increase in activation noted in the medial gastrocnemius, peroneus longus, rectus femoris and gluteus medius respectively). Our results are consistent with previous studies that have assessed lower extremity mechanics during high heeled shoe use [2], and provide new insights about the demands placed on the gluteus medius and peroneus longus during the use of high heeled shoes.

We have previously shown that the step down task places significant demands on joint motion [4]. The findings of the current study provide objective evidence demonstrating that the step down task places increased demands on lower extremity musculature. Increased muscle activation in response to footwear and/or activity, may contribute to increased joint loading, and consequent foot pain and/or the evolution of degenerative changes. Additionally, some studies have proposed that the increased muscle activation noted with high heeled shoe use may predispose wearers to muscle fatigue and overuse injuries [1,2]. Longitudinal studies in individuals who are regular wearers of high heeled shoes are indicated to explore the implications of the current findings in individuals at risk for foot pain.

**REFERENCES**


**Table 1:** Summary of mean and standard deviation (SD) peak muscle activation (expressed as a percentage of peak activation during a low heel walking trial) during walking and step down. Each chart depicts peak muscle activation expressed as a percentage of peak activation during a low heel walking, using low heels (blue squares) and high heels (red circles).

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Peroneus Longus</th>
<th>Gluteus Medius</th>
<th>Medial Gastrocnemius</th>
<th>Rectus Femoris</th>
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<tbody>
<tr>
<td></td>
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<td>SD</td>
<td>Mean</td>
<td>SD</td>
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<tr>
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