The Effect of Textured Insoles on Postural Control in Double and Single Limb Stance

Dawn M. Corbin, Joseph M. Hart, Patrick O. McKeon, Christopher D. Ingersoll, and Jay Hertel

Context: Increased plantar cutaneous afferent information may improve postural control. Objective: To compare postural control measures between balance conditions with and without textured insoles. Design: crossover trial. Setting: Research Laboratory. Patients or Other Participants: 33 healthy subjects (27.4 ± 9.1yrs, 172.6 ± 10.3 cm, 75.4 ± 16.4 kg). Intervention(s): Subjects performed 24, 10-second bipedal and unilateral stance balance trials with eyes opened and eyes closed, with and without a textured insole in subjects’ shoes. Main Outcome Measures: Average velocity and area of center of pressure (COP) excursions. Results: We observed an interaction among balance conditions during bilateral stance, but not during unilateral stance. On average, subjects exhibited greater area and velocity of COP excursions with eyes closed compared to eyes opened. Significant differences in area and velocity of COP excursions were observed during bilateral stance only when subjects were not wearing textured insoles. There were no significant differences while subjects balanced in bilateral stance with textured insoles. Conclusions: Increased afferent information from textured insoles improves postural control in bilateral stance.

Postural control is organized in a hierarchical manner and is influenced by input from the vestibular, visual, and somatosensory systems. The somatosensory system is constantly processing information from afferent receptors from the skin, joints, muscles, and tendons and continuously making adjustments to maintain equilibrium and dynamic balance. Afferent information from the plantar cutaneous surface of the foot is important in maintaining standing balance and postural control. Efficient postural control is important in maintaining balance and avoiding falls during gait and other activities.

The plantar surfaces of the feet serve as an interface between the body and the ground and play an important role in postural control. The contribution of afferent input from the plantar cutaneous surface of the foot to postural control has been studied through local anesthesia and ischemic blocking, while others have evaluated the effect of hyperstimulating plantar afferent receptors through stimuli.

Dawn M. Corbin is with Floyd Sports Medicine, Rome, GA. Joseph M. Hart and Patrick O. McKeon are with the Department of Orthopedic Surgery at the University of Virginia in Charlottesville. Christopher D. Ingersoll and Jay Hertel are with the Department of Human Services at the University of Virginia in Charlottesville.
such as vibration. The plantar cutaneous receptors contribute substantially to the maintenance of postural control; however the extent of their contribution remains unclear. In addition, reducing plantar cutaneous afferent input through surface cooling (ie, cryotherapy) impairs postural control. Little is known, however, about how increased plantar cutaneous stimulation affects postural control. Improved postural control through altered afferent information from plantar cutaneous receptors may improve outcomes with various injured or disabled populations. Therefore, the purpose of this study was to compare postural sway measures (velocity and area of center of pressure excursions) between various balance conditions with and without textured insoles.

**Methods**

This study consisted of an experimental, crossover, 2×2×2 factorial design. The independent variables were texture (texture insole, no textured insole), stance (unilateral, bilateral), and vision (eyes opened, eyes closed). The dependent variables were area of the 95% center of pressure (COP) excursion confidence ellipse and average velocity of COP excursions during balance trials.

**Subjects**

Thirty-three subjects (16 male, 17 female, age = 27.4 ± 9.1 years, height = 172.6 ± 10.3 cm, mass = 75.4 ± 16.4 kg) volunteered for this study. Subjects had no ankle or knee injuries during the six months prior to participating and did not suffer from any neurological conditions that might affect their balance, such as vestibular disorders or diabetes, and were not taking any medications that affected their balance. All subjects read and signed an informed consent form prior to participating. This study was approved by our university’s institutional review board.

**Instruments**

We used the AccuSway PLUS Balance Platform (Advanced Mechanical Technology, Inc., Watertown, MA) to collect forces and moments in three planes while subjects were balancing. Analog signals from the force plate were sampled at 50Hz and low pass filtered at 10Hz (Butterworth) post hoc. COP locations were calculated with Balance Clinic Software (Version 1.0, Advanced Mechanical Technology, Inc., Watertown, MA). The software also calculated COP velocity and area measures for each trial.

Textured insoles used in this study were made from a plastic floor matting material purchased at a local hardware store. The thin floor matting material had small rounded plastic nubs that were raised about 1/4 cm off the plastic surface. The plastic material was cut in the shape of a shoe orthotic (Figure 1). There were multiple insoles made encompassing both men’s and women’s whole and half sizes. All subjects wore standard, thin cotton socks (Athletech, Troy, MI). Although we may have achieved greater plantar cutaneous stimulation if subjects were barefooted, this condition best resembled an athletic or active setting.
Testing Procedures

All subjects participating in this study wore their own athletic shoes for testing. Preliminary foot measurements included shoe length as the distance (cm) from the heel to the toe, shoe width as the distance (cm) from the medial to lateral side of the foot at the metatarsal heads.

Each subject performed three, 10-second balance trials in the following conditions: (1) bilateral stance, eyes open, no insoles; (2) bilateral stance, eyes open, textured insoles; (3) bilateral stance, eyes closed, no insoles; (4) bilateral stance, eyes closed, textured insoles; (5) unilateral stance, eyes open, no insole; (6) unilateral stance, eyes open, textured insole; (7) unilateral stance, eyes closed, no insole; and (8) unilateral stance, eyes closed, textured insole. The order of trials was counterbalanced. For the texture condition, subjects either balanced with nothing in their shoe or a textured insole was inserted. For the bilateral stance condition, subjects were instructed to stand comfortably with their hands across their chest with legs approximately shoulder-width apart. For the unilateral condition, the subjects were instructed to keep their contralateral knee bent to 90° while balancing on their dominant leg, with their hands across their chest. Leg dominance was determined by asking subjects what leg they would use to kick a ball. For the visual condition, subjects kept their head in a neutral condition and either closed their eyes or focused on an “X” that was drawn on the wall 1m in front of them at eye-level. Subjects were given 30 seconds rest between each trial.

If a subject deviated significantly away from the original testing position while balancing, the trial was discarded and repeated. For example, if subjects opened their eyes during a closed eye trial, touched down their contralateral leg during a unilateral stance trial, or stepped off the force plate while measurements were being taken, the trials would be discarded and tested over. If more than 3 trials per condition were terminated due to deviations, a subject was discarded from participation. In this study, no subjects were discarded due to an inability to balance.
The dependent variables were the area and velocity of COP excursions. For each measure, we calculated the average from the three trials for each condition. Area of a 95% confidence ellipse is the area of an ellipse needed to encompass 95% of the COP excursions during the trial. Velocity represents the mean speed of COP excursions across a trial. Higher values for both COP excursion area and velocity are thought to represent increased postural instability.

**Statistical Analysis**

For each dependent measure, we performed separate 2×2 (eye condition × texture) ANOVAs for the unilateral (dominant limb) and bilateral stance conditions. In the event of significant interaction, we performed post-hoc t-tests to identify specific differences. The alpha level was set a priori at $P < 0.05$. For the post hoc tests we used a Bonferonni corrected alpha level of $P \leq 0.05/4 = 0.013$. All statistics were calculated with SPSS version 12.0 (SPSS Inc., Chicago, IL).

**Results**

There was a significant interaction between eyes and texture for COP area measures in bilateral stance ($F_{1,32} = 5.11, P = 0.03$). Without textured insoles, there was a significant increase in COP area with eyes closed compared to eyes open ($t_{32} = -2.9, P = 0.008$). However, with textured insoles, there was no significant difference between eyes open and closed conditions ($t_{32} = -0.53, P = 0.60$; Figure 2).

For the average velocity of COP excursions in bilateral stance, there was a significant interaction between eye and texture conditions ($F_{1,32} = 4.57, P = .04$). Without textured insoles, when subjects were asked to balance with their eyes

---

**Figure 2** — Average area of center of pressure 95% confidence ellipse (with SEM bars) during bilateral stance for eyes open and eyes closed conditions, with and without textured insoles (*$P = 0.008$).
closed, their velocity measurements were larger than with eyes open ($t_{32} = -5.4, P < 0.001$). Conversely with textured insoles, there was not a significant difference between eyes open and closed measurements ($t_{32} = -2.0, P = 0.06$; Figure 3).

In unilateral stance area measures, there was not a significant eye by texture interaction ($F_{1,32} = 0.76, P = .60$); however, there was a significant main effect for eye condition ($F_{1,32} = 264.40, P < .001$) with eyes closed measures being significantly higher than eyes open measures. There was no significant main effect for texture ($F_{1,32} = 1.25, P = .20$; Figure 4).

Similarly, in unilateral limb stance area measures, there was a significant main effect for eye condition ($F_{1,32} = 192.12, P < .001$) but no significant main effect for texture ($F_{1,32} = 1.71, P = .27$) or significant interaction ($F_{1,32} = 0.29, P = .61$; Figure 5). Means and standard deviations are provided in Tables 1 and 2.

---

**Figure 3** — Average velocity of COP excursions (with SEM bars) during bilateral stance for eyes open and eyes closed conditions, with and without textured insoles (*$P = 0.04$).

**Figure 4** — Average area of COP excursions 95% confidence ellipse (with SEM bars) during dominant limb stance for eyes open and eyes closed conditions, with and without textured insoles. *On average, unilateral stance COP area was greater with eyes closed, $P < .001$. 

Figure 5 — Average velocity of COP excursions (with SEM bars) during dominant limb stance for eyes open and eyes closed conditions, with and without textured insoles. *On average, unilateral stance COP velocity was greater with eyes closed, \( P < .001 \)

**Table 1  Dominant Leg Area and Velocity Mean and Standard Deviations**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity EO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>5.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Texture</td>
<td>10.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Velocity EC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>4.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Texture</td>
<td>9.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Area EO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>9.5</td>
<td>5.4</td>
</tr>
<tr>
<td>Texture</td>
<td>33.3</td>
<td>15.1</td>
</tr>
<tr>
<td>Area EC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>8.3</td>
<td>6.7</td>
</tr>
<tr>
<td>Texture</td>
<td>30.6</td>
<td>3.1</td>
</tr>
</tbody>
</table>

**Table 2  Bilateral Stance Area and Velocity Mean and Standard Deviations**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity EO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Texture</td>
<td>1.4</td>
<td>0.3</td>
</tr>
<tr>
<td>Velocity EC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Texture</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Area EO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Texture</td>
<td>2.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Area EC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Texture</td>
<td>1.7</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Discussion

Postural control improved while subjects wore textured insoles during bilateral, eyes-closed stance. This change in postural control may be due to hyperesthesia of the plantar surfaces of the feet, resulting in increased cutaneous afferent receptor activity while subjects stood on the textured insoles. When subjects balanced in bilateral and unilateral stance, there were considerable differences in COP area and velocity between eyes closed and eyes opened conditions. Textured insoles appear to provide surrogate afferent input that is sufficient to accommodate for the loss of vision in COP area measures, but not both vision and proprioception (ie, unilateral stance).

In the current study, lack of visual input while in double or single leg stance affected postural control. This is evident through visual inspection of the data in Figures 4 and 5 showing obviously large effect sizes in area (Cohen’s $d = 1.56$) and velocity of COP (Cohen’s $d = 1.58$) excursions between eyes closed and eyes opened conditions while in single limb stance. Effect sizes for the change in COP area (Cohen’s $d = 0.27$) and velocity (Cohen’s $d = 0.76$) between visual conditions was less profound while subjects balanced in double limb stance. This suggests the effect of visual input on area and velocity of COP excursions was greater during single leg stance than during bilateral stance. Therefore, loss of visual input appeared to influence postural control measures less during bilateral stance (while the central nervous system received afferent input from both plantar surfaces).

Visual, vestibular, and proprioceptive modalities contribute to postural control. The central nervous system receives afferent information from various receptors and creates an efferent response while controlling balance and posture. It is well documented that reduced information from one of these sensory modalities will affect postural control.\textsuperscript{13-15} For example, deteriorating measures of postural control are common while standing with the eyes closed (ie, loss of visual modality). In the presence of diminished afferent information from more than one sensory modality (ie, visual by means of closing the eyes and proprioceptive by standing on only one leg), there was a large effect on postural sway. Increased afferent information due to wearing textured insoles was not able to compensate for deteriorated postural control while in single leg stance. Conversely, with loss of only one sensory modality (ie, visual by means of closing the eyes during bilateral stance), the effect on postural control was not as profound. In this condition, increased plantar cutaneous afferent information from both feet was able to compensate for deteriorated postural control due to loss of visual modality alone. It is apparent that the textured insoles used in this study do not affect postural control enough to overcome the large effect of visual loss on postural control.

There are few studies investigating the role of plantar cutaneous hyperesthesia on postural control. Vibration-induced stimulation of plantar surface of the feet elicited changes in sway measures during stance suggesting that cutaneous afferent information from plantar surfaces may affect postural control.\textsuperscript{4,6,7} The current study is the first to evaluate the effects of simple, affordable, and easily fabricated insoles on postural control. Previously, custom fit, rigid foot orthoses have shown conflicting findings regarding postural control. Rear foot orthotics may\textsuperscript{16} or may not\textsuperscript{17} affect postural control in athletes with lateral ankle sprains but, but do improve postural control in persons with excessively pronated feet.\textsuperscript{18} Improved bony con-
gruency provided by custom made rigid orthotics may contribute to improved postural control; however, this was beyond the scope of this study and is an area for future investigations. Currently, it remains unclear what specific influence insoles or orthotics has on postural control in injured populations. In the current study, a licensed, certified athletic trainer (DMC) visually inspected subjects’ foot types (9% pes cavus, 37% pes planus, 54% normal); however, there was no correction for foot-type in our analysis. The insoles used were not custom fit to each subjects’ foot contour, instead a flat cut-out (Figure 1) was placed in the shoes. Therefore, the total surface area affected by the textured insoles used in this study may have been different among the foot types. For example, a subject with pes planus feet may have had more plantar cutaneous contact than a subject with pes cavus feet.

The current study evaluated changes in postural control in healthy subjects treated with textured insoles. Certain patient populations experience risk for injury and falls due to poor postural control. For example, plantar cutaneous sensory deficit in diabetic patients affects postural control. Further, measures of postural control have been used to identify neuromuscular impairments in persons with lower extremity injuries such as ankle sprains, anterior cruciate ligament injuries, and low back pain. Poor postural control is also common in older individuals who tend to fall often. In clinical settings, textured insoles may supplement somatosensation through increased plantar cutaneous afferent receptor stimulation. The impact textured insoles has on unilateral and bilateral postural control in injured populations is an appropriate area for controlled clinical trials.

In conclusion, we observed consistently poorer postural control during single and double limb balance trials when subjects did not have visual input (ie, eyes closed). While in bilateral stance with textured insoles inserted into the shoe and without visual input, subjects’ postural control pattern resembled that of bilateral stance with the eyes opened. Although we do not know how textured insoles would perform with clinical populations, this intervention poses a mechanism by which we may be able to compensate for diminished sensory modalities in patients with poor postural control.

References


---

**EDITORIAL MISSION**

*Journal of Sport Rehabilitation*

The editorial mission of the *Journal of Sport Rehabilitation (JSR)* is to advance the understanding of all aspects of sport rehabilitation, particularly in the areas of therapeutic exercise, therapeutic modalities, injury evaluation, and the psychological aspects of rehabilitation. *JSR* publishes original research, commentary, scholarly reviews, and case studies that directly affect the management and rehabilitation of injuries incurred during sport-related activities, irrespective of the individual’s age, gender, sport ability, level of fitness, or health status. The journal is intended to provide an international, multidisciplinary forum to serve the needs of all members of the sports medicine team, including athletic trainers/therapists, sport physical therapists/physiotherapists, sports medicine physicians, and other involved professionals.

**Original Research Reports.** *JSR* publishes original research reports on all aspects of the sport and exercise rehabilitation process.

**Research Reviews.** *JSR* encourages the submission of review articles that synthesize the findings of a series of research studies to arrive at generalizations pertinent to sport rehabilitation. Meta-analyses and critical literature reviews are desirable.

**Commentary.** Commentaries on selected original research reports and research reviews are published to encourage discussion and interject intellectual diversity into emerging theory.

**Case Studies.** *JSR* also publishes case studies that present carefully recorded observations of rehabilitation programs or processes among sport and exercise participants. Case studies must present unusual or rare injuries or conditions or present unique approaches to common injuries or conditions.

**Sport Rehabilitation Forum.** *JSR* also offers a forum for expressing opinions about sport rehabilitation.

**Media Reviews.** The journal also publishes book, video, and software reviews.

*JSR* will also publish special issues that are oriented toward a specific sport rehabilitation theme. The editor solicits special issue topic suggestions.