

## Effect of Orthotics on Postural Sway Following Inversion Ankle Sprain

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Guskiewicz, K.M., & Perrin, D.H. (1996). Effect of orthotics on postural sway following inversion ankle sprain. Journal of Orthopedic and Sports Physical Therapy, 23:326-331.

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### **Abstract:**

Orthotic devices have been shown to successfully modify selected aspects of lower extremity mechanics and enhance foot stability during the support phase of running. It was hypothesized that orthotic intervention would relieve excessive strain on the ankle ligaments and reduce postural sway, especially in subjects with acute ankle sprains. The primary purpose of this study was to determine if orthotics would reduce postural sway in injured and uninjured subjects. Thirteen subjects with acute inversion ankle sprains and 12 uninjured subjects were assessed for postural sway on the Balance System under two treatment conditions (orthotic and nonorthotic) and four platform movements. A three-factor repeated measures analysis of variance revealed a significant group x treatment interaction, suggesting that postural sway with orthotic intervention improved significantly more in injured subjects than in uninjured subjects. A significant platform movement x treatment interaction, furthermore, revealed that postural sway for the four movement conditions was dependent upon treatment (orthotic vs. no orthotic). Tukey post hoc analysis revealed that orthotic intervention significantly reduced postural sway when the platform moved in the medial/lateral plane and inversion/eversion plane. This research suggests that custom-fit orthotics may restrict undesirable motion at the foot and ankle and enhance joint mechanoreceptors to detect perturbations and provide structural support for detecting and controlling postural sway in ankle-injured subjects.

### **Article:**

Inversion ankle sprains are one of the most frequently occurring injuries among athletes and physically active people. The lateral ankle ligaments are usually disrupted to some degree with the forced inversion mechanism accompanying many ankle injuries (6,7,19,23). These ligaments (calcaneofibular, anterior talofibular, posterior talofibular) are responsible for approximately 87% of resistance to inversion of the talus when the ankle is unloaded or nonweight bearing. Therefore, injuries to the lateral ligaments may cause partial deafferentation and decreased proprioception, resulting in ankle instability. When the foot is loaded, however, the articular surfaces of the ankle joint become the sole source of inversion and eversion stability (23). Therefore, it would appear that ligamentous instabilities occur during loading and unloading of the ankle joint when the articular surfaces are not optimally aligned within the mortise. Furthermore, once the ankle is fully loaded, it would appear that any instabilities would be due to malalignments at the talocrural joint.

Various treatments for the management of acute ankle injuries have been proposed and are well documented in the literature (7,9,17,19, 30). Initially, these treatment protocols include cryotherapy, elevation, compression, and nonsteroidal anti-inflammatory medications to control pain and inflammation. Active range of motion exercises, progressive resistive exercises, proprioceptive training, and functional training are then prescribed as tolerated by the athlete. Return to activity usually requires supportive taping or bracing, especially in athletes who experience chronic instability.

The effectiveness of supportive taping and/or bracing following ankle injury is well documented in the literature (3,13,18,29). Very few studies, however, have focused on the subtalar joint and its role as a major link between

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the foot and structures higher up the kinetic chain, ie., the talocrural joint. Parlaska et al (16) reported that subtalar joint motion increases following a lateral ankle sprain, thus affecting the position of the talus at the talocrural joint.

Several studies have addressed the compensatory foot and ankle mechanics which accompany foot abnormalities (1,11,14,20,22,24,30). Orthotic devices have been shown to successfully modify selected aspects of lower extremity mechanics and enhance foot stability during the support phase of running (1,14,21,22). In most cases, the orthotic device is used to eliminate the need for compensatory pronation by reducing calcaneal eversion (14,21). Some research has reported total resolution in 75% (11) and 56% (22) of patients with overuse injuries. Orteza et al (15) is the only study of the effect of foot orthotics on subjects with ankle injuries. They reported that subjects with ankle sprains demonstrated significantly higher "time out of balance" scores than those without ankle injuries when measured on a stable platform. They also reported that molded orthotics had a significant effect on improving "time out of balance" scores for those subjects with ankle sprains. They concluded that much of the balance performance deficit created by the ankle injury was restored by molded orthotics. The orthotics, however, failed to improve balance scores in uninjured subjects.

Postural sway is the measurement of the time and distance a subject spends away from an ideal center of balance. Although a person's calculated center of pressure or center of balance is not identical to their center of gravity, when sampled adequately, it accurately reflects the mean position of the vertical projection of the center of gravity (10). Because of this relationship, measurement of a person's center of pressure has been used as a method of quantifying postural stability. Since 1965 (6), investigators have theorized that if ankle injuries cause partial deafferentation and functional instability, a person's postural sway should be altered due to a proprioception deficit. Despite Freeman's theory, conflicting findings (5,15,26,27) suggest that research has not adequately answered the question as to whether or not subjects with ankle sprains demonstrate increases in postural sway.

Therefore, residual ankle disability is not well understood. Late symptoms, such as recurrent sprains or fear of the foot giving way, have only partly been explained by mechanical instability (8,25,28). Previous research has focused on orthotic intervention in treating conditions such as peroneus longus tendinitis, anterior compartment syndrome, Achilles tendinitis, tibialis anterior tendinitis, and stress fractures, but has not adequately addressed intervention for acute ankle sprains. If the articular surface at the ankle joint is the sole source of inversion and eversion stability during walking and running, it would seem that orthotic devices designed to optimize subtalar and talocrural alignment would relieve excessive strain on the ligaments of the ankle.

The purpose of this study was to determine if subjects with acute inversion ankle sprains demonstrated more postural sway than subjects without ankle sprains and if orthotic intervention would reduce postural sway in injured and uninjured subjects. We hypothesized that there would be an increase in postural sway for the ankle-injured subjects and that all subjects would improve postural sway scores with orthotic intervention. We also expected ankle-injured subjects would demonstrate greater improvement on postural sway than uninjured subjects with orthotic intervention.

## METHOD

### *Subjects*

Thirteen subjects (seven males and six females, 18.1  $\pm$  5.8 years, height = 173.74  $\pm$  9.91 cm, weight = 65.8  $\pm$  10.32 kg) with acute ankle sprains at the time of testing and 12 subjects (six males and six females, 25.7  $\pm$  6.6 years, height = 176.28  $\pm$  8.89 cm, weight = 70.32  $\pm$  12.14 kg) with no history of ankle sprains participated in this study. Acute was defined as an ankle sprain that had occurred within 21 days of testing. All injured subjects had a pain-free range of motion and were fully weight bearing at the time of testing (17.7  $\pm$  2.8 days postinjury). Subjects consisted of volunteers from a local university and a local private high school.

### *Procedures*

Approximately 10 days prior to testing, subjects reviewed and signed an informed consent form approved by a university institutional review board. Each subject was evaluated for structural malalignments and gait abnormalities before being fitted for a pair of custom orthotics (Foot Management, Inc., Pittsville, MD). A foam casting block was used to produce an impression negative of the foot in a neutral subtalar joint position. This position represents the point where the head of the talus is congruent with the medial aspect of the body of the navicular. This was established from the seated position with right angles maintained at the hip, knee, and ankle. The heel was then passively pressed into the foam approximately 2 inches while maintaining pressure against the medial head of the talus with the left thumb, so that. no motion was permitted between the head of the talus and the body of the navicular. Using the other hand, the remainder of the foot was pressed evenly into the foam to the same depth as the heel. This was repeated for the opposite foot. The negatives were sent to the manufacturer for production of the orthotics with instructions to correct for any malalignments revealed during the evaluation.

Postural sway during a single limb stance was measured using the Balance System (Chattecx Corporation, Chattanooga, TN). This instrument measured vertical reaction forces using four force transducers placed under the medial and lateral aspects of the heel and forefoot. The force transducers rested upon a platform that rotated about a medial- lateral axis relative to the subject, allowing for various movement patterns. The angular perturbation of the Chattecx Balance System has a period of 8.33 seconds and is constructed as a sinusoidal, from horizontal to 4° posterior tilt (dorsiflexion) and back to the horizontal. In addition, the period can be varied from 0 to 8.3 seconds, and the subject can also be tilted from horizontal to a plantar flexed position as well as going from 4° plantar flexion through 4° dorsiflexion to level again. Fluctuations in displacement of the center of pressure reflected the amount of postural sway during four independent platform conditions (stable, inversion/eversion, plantar flexion/dorsiflexion, and medial/lateral). Postural sway, as assessed by the Chattecx Balance System, is the distance expressed in centimeters that an individual travels away from their center of balance. Center of balance is the point between the feet where the ball and heel of each foot has 25% of the body weight (4).

Group	Number of Subjects	Order
Injured	4	Stable, inversion/eversion, plantar flexion/dorsiflexion, medial/lateral
	3	Inversion/eversion, plantar flexion/dorsiflexion, medial/lateral, stable
	3	Plantar flexion/dorsiflexion, medial/lateral, stable, inversion/eversion
	3	Medial/lateral, stable, inversion/eversion, plantar flexion/dorsiflexion.
Uninjured	3	Stable, inversion/eversion, plantar flexion/dorsiflexion, medial/lateral
	3	Inversion/eversion, plantar flexion/dorsiflexion, medial/lateral, stable
	3	Plantar flexion/dorsiflexion, medial/lateral, stable, inversion/eversion
	3	Medial/lateral, stable, inversion/eversion, plantar flexion/dorsiflexion

**TABLE 1.** Orders of movement conditions for random assignment of subjects.

Deviation from the center of balance in any direction represents postural sway. The sway index, produced by the device, reflects the degree of scatter of data about the subject's center of balance. The force platform measurements are interfaced with software that filters data collected at 100 cycles/sec so that it can be sampled and analyzed at approximately 15 cycles/sec. Extraneous high frequency is virtually eliminated using this technique. Sway index is then calculated by determining the distance from the subject's center of balance for each of the data points according to the following formula:

$$\text{Sway index (cm)} = \sqrt{\frac{\text{sum of (x cm}^2 \cdot \text{y cm}^2)}{\text{number of points collected}}}$$

Mattacola and Perrin (12) investigated intertester reliability of the Chattecx Balance System during single leg static and dynamic testing and reported intraclass correlation coefficients (and standard error of measurements in cm), ranging from .41 (.21) to .90 (.06). Furthermore, Byl and Sinnott (2) investigated intratester and intertester reliability of the instrument and reported correlation coefficients of .92 and .90, respectively.

Subjects were tested under two treatment conditions—orthotic and nonorthotic. Testing order was determined using a randomized schedule, where six subjects in each group were randomly assigned to be tested first with orthotics and the remaining subjects in each group tested first without orthotics. Orders of movement conditions were also randomly assigned (Table 1). Subjects received a

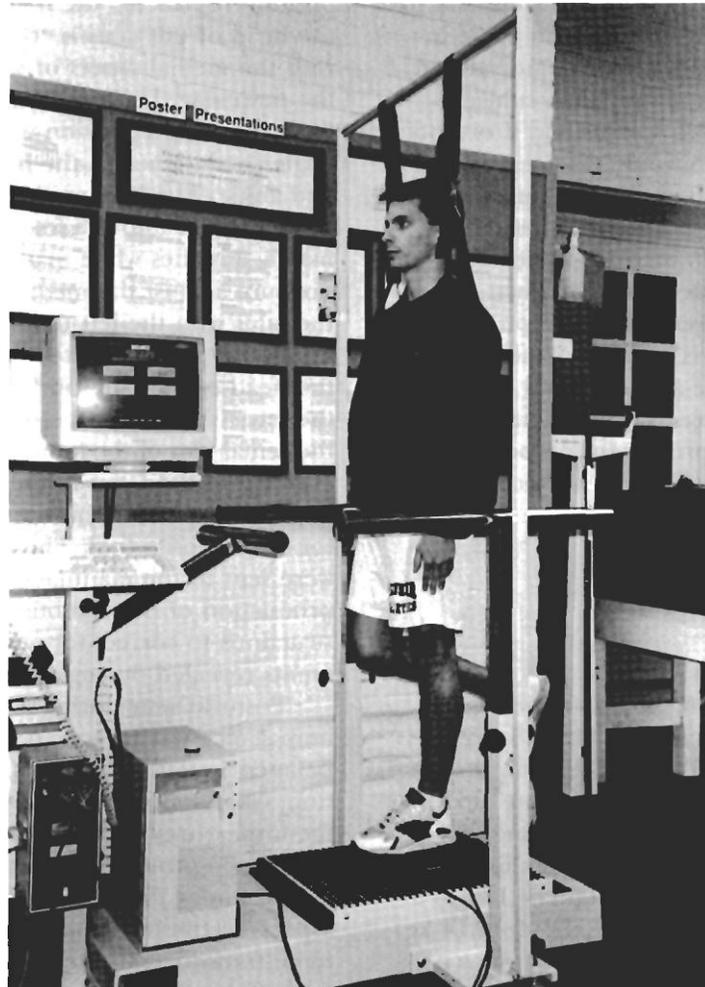


FIGURE 1. Subject positioned on the Chattecx Balance System during single leg static test.

5-minute rest between tests. Low-top athletic shoes with removable in-soles were worn for testing. For the orthotic treatment condition, the insoles were replaced with the subject's custom-made orthotics.

Subjects were positioned on the Balance System with arms at their sides, eyes open, the knee of the unsupported leg flexed to approximately  $70^\circ$ , and the hip of the unsupported leg flexed to  $20^\circ$  (Figure 1). Although subjects received no visual feedback during testing, they were given a practice trial prior to testing which allowed them to observe their postural sway on the monitor. This was done in an attempt to familiarize subjects with the task of minimizing their postural sway. Subjects were instructed to focus on an object approximately 6 feet away while minimizing their postural sway during each 10-second test.

### *Statistical Analysis*

Statistical analyses were performed using SPSS Release 4.1 statistical package (SPSS, Inc., Chicago, IL). A three-factor mixed model analysis of variance (ANOVA) with repeated measures over two variables [treatment

condition (orthotics or no orthotics) and platform movement (stable, inversion/eversion, plantar flexion/dorsiflexion, medial/lateral shift)] was performed on the postural sway data. The between subject factor was group (injured, uninjured). An alpha level of  $p < .05$  was set *a priori*.

## RESULTS

The means (standard deviations) of postural sway measurements obtained for injured and uninjured subjects under all conditions are presented in Table 2. The analysis of variance revealed a significant group by treatment interaction ( $F [1,23] = 4.24, p < .05$ ), which suggested that improvement in postural sway with orthotic intervention was dependent upon group (injured vs. uninjured).

	No Orthotics	With Orthotics
Stable		
Injured	.80 (.22)	.82 (.32)
Uninjured	.63 (.18)	.87 (.32)
Inversion/Eversion		
Injured	1.07 (.31)	.86 (.19)*
Uninjured	.89 (.19)	.87 (.21)
Plantar/Dorsiflex		
Injured	1.39 (.49)	1.33 (.48)
Uninjured	1.14 (.27)	1.13 (.33)
Medial/Lateral		
Injured	1.63 (.27)	1.26 (.21)*
Uninjured	1.39 (.35)	1.34 (.32)

\* Significantly different ( $p < .05$ ).

**TABLE 2.** Mean postural sway measurements for ankle-injured and uninjured subjects presented as sway index in cm  $\pm$  SD for the four movement trials

The ANOVA table for the analysis is presented in Table 3. Postural sway with orthotic intervention improved significantly more in injured subjects than in uninjured subjects (Figure 2).

A significant platform movement by treatment interaction ( $F [3,69] = 3.27, p < .05$ ) furthermore revealed that postural sway for the four movement conditions was dependent upon treatment (orthotic vs. no orthotic). Tukey post hoc analysis revealed that orthotic intervention significantly reduced postural sway when the platform moved in the medial/lateral plane and inversion/eversion plane ( $p < .05$ ) (Figure 3). Neither the group X movement X treatment interaction nor group X movement interaction were significant at the .05 level.

## DISCUSSION

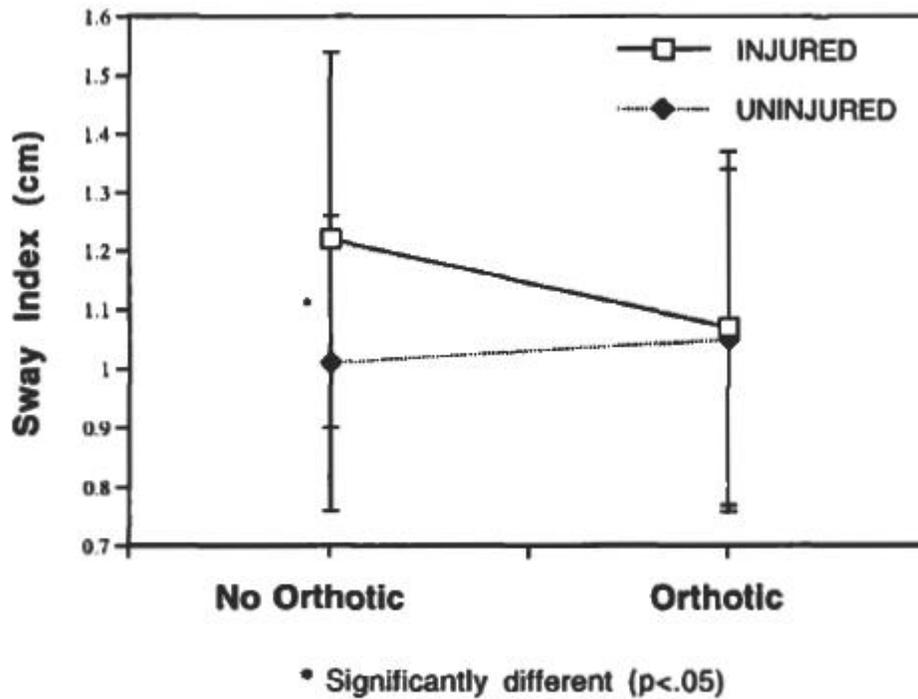
The intervention of orthotics significantly reduced postural sway in ankle-injured subjects as compared with uninjured subjects. Postural sway scores averaged across all movement patterns for injured subjects were reduced by .15 cm as compared with .01 cm for uninjured subjects following orthotic intervention. The significant platform condition X treatment interaction (Figure 3) suggests that improvements occurred during the medial/lateral and inversion/eversion movement conditions. These results suggest that the orthotics provided increased structural support to the medial and lateral sides of the foot. We theorize that the added support prevents excessive movement at the subtalar joint as well as at the talocrural joint. This is of importance during weight bearing since optimal alignment at the mortise is necessary for normal mechanics. Additionally, the orthotic may have placed the ligaments at the talocrural joint in a more optimal position to allow joint mechanoreceptors to detect perturbations to postural sway. It is also speculated that the orthotic offers enhanced tactile stimulation to the surface of the foot and thus improved somatosensory feedback necessary for balance control. Twenty-one of the 25 subjects reported feeling more stable and more comfortable wearing the orthotics as opposed to not wearing them during the dynamic test. Clinicians should consider athletes' subjective assessment of ankle stability when intervening with rehabilitative and/or support techniques.

Source of Variance	SS	df	MS	F	p
<b>Between subjects effects</b>					
Within cells	6.60	23	.29		
Group	.90	1	.90	3.13	.090
<b>Within subjects effects</b>					
Within cells	5.81	69	.08		
Movement	14.15	3	4.72	56.00	.001
Group X movement	.19	3	.06	.74	.534
Within cells	1.42	23	.06		
Treatment	.33	1	.33	5.41	.029*
Group X treatment	.26	1	.26	4.24	.050*
Within cells	2.97	69	.04		
Movement by treatment	.42	3	.14	3.27	.026*
Group X movement X treatment	.17	3	.06	1.34	.267

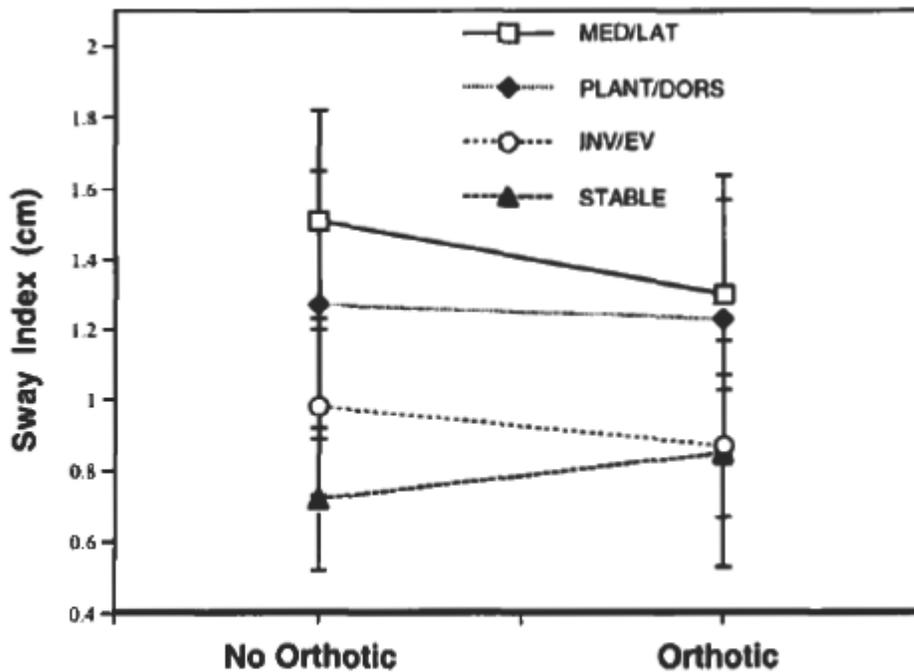
\* Significant  $p < .05$ .

**TABLE 3.** Analysis of variance table for repeated measures mixed model three within and one between subject variables.

Tukey post hoc analysis revealed that subjects with acute ankle sprains demonstrated significantly more postural sway than uninjured subjects without orthotic intervention. This is consistent with findings by Cornwall and Murrell (5), Freeman (6), and Orteza et al (15) and contradict those of Tropp et al (26,27). The two studies by Tropp et al (26,27) suggest that individuals with a previous history of ankle injury do not exhibit increases in postural sway. The latter study (27), however, concluded that players with postural sway values greater than two standard deviations above the mean of a control group had a higher risk of injury during the remainder of the season. Freeman (6) revealed that proprioceptive deficits were responsible for symptoms of "giving way" in ankles and feet with ligamentous injuries and theorized that impaired stability while balancing on an injured foot implied a disturbance of proprioception. There are conflicting results in the literature concerning postural sway in subjects with ankle sprains, and several of these studies contradict Freeman's theory. More recent studies by Orteza et al (15) and Cornwall and Murrell (5) suggest that people with acute inversion ankle sprains and/or a history of inversion ankle sprains are less stable in single limb stance as compared with noninjured control groups. We feel these subjects best resemble the subjects in the current study, and our results are consistent with those of Orteza et al (15) and Cornwall and Murrell (5). Acute ankle-injured subjects demonstrate deficits in postural stability when compared with control subjects.



**FIGURE 2.** Postural sway measurements averaged across all movement patterns are presented as sway index in cm ( $\pm$  SD) for the two groups.



**FIGURE 3.** Postural sway measurements averaged across the two groups for the various movement patterns are presented as sway index in cm ( $\pm$  SD) for each movement pattern: Stable (stable platform), Inv/Ev (platform moving into inversion and eversion), Plant/Dors (platform moving into plantar flexion and dorsiflexion), and Med/Lat (platform gliding medially and laterally).

The effectiveness of orthotic intervention for correcting malalignments of the foot has been well documented in the literature (1,14,21,22,24). Orteza et al (15) proposed that orthotics help to control the excessive pronation commonly seen in many athletes and that orthotic intervention prevents undue stress to the injured anterior

talofibular ligament. Our findings are consistent with Orteza et al (15), which also revealed improvements in balance for injured subjects, but not uninjured subjects. The current study, however, included balance assessment under dynamic conditions. It is proposed that dynamic conditions more closely resemble functional activity and may be more valuable in considering athletic activity.

All of the 25 subjects continued wearing the orthotics during their respective seasons or recreational activities. At 10 months follow-up, none of the injured subjects had reinjured their ankle nor had any of the uninjured subjects suffered an injury. This research suggests that maintaining the foot and ankle in a more neutral position through orthotic intervention is useful in helping to control postural sway in people with acute ankle injuries. Thus, the use of orthotics may be especially beneficial for treating acute ankle sprains as they allow for better subtalar and talocrural alignment with a concomitant decrease in stress to the injured ligaments.

## CONCLUSIONS

Ankle-injured people sway more than uninjured people when assessed on a single-leg stance test. Orthotic intervention for acute ankle-injured people appears to be a useful strategy in reducing this increased postural sway. Furthermore, ankle-injured subjects report feeling more stable and more comfortable during balance testing when wearing orthotics. Therefore, the use of orthotics may be a useful modality in facilitating recovery and return to activity following acute ankle sprain.

## ACKNOWLEDGMENTS

We thank Foot Management, Inc. for manufacturing and providing the orthotics for this study.

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