Research Report

Ankle muscles activation with the StepRight Stability System

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Background and Purpose: Ankle sprains often lead to chronic ankle instability, with deficits in strength, proprioception, and neuromuscular control. Balance devices are commonly used in rehabilitation, but the StepRight Stability System (SRSS), a shoe-mounted unstable platform, has not been objectively evaluated. This study quantified and compared fibularis longus (FL), tibialis anterior (TA), and medial gastrocnemius (mGC) activation during four exercises performed on a firm surface versus while wearing the SRSS.
Methods: Twenty healthy adults volunteered; data from two outliers were excluded. Surface electromyography recorded FL, TA, and mGC activity of the dominant limb during single-leg stance, single-leg squat, forward lunge, and side lunge. Exercises were completed in athletic shoes on a firm surface and with the SRSS in randomized order. Maximum voluntary isometric contractions normalized EMG data. Three 15-second trials were performed per condition, with the middle five seconds analyzed. Reliability was assessed with intraclass correlation coefficients, and 2×4 repeated-measures ANOVAs with post hoc paired t tests evaluated effects of surface and exercise.
Results: Significant main effects for exercise and surface, and significant surface-by-exercise interactions, were found for FL and TA. Both muscles showed significantly greater activation during single-leg stance and single-leg squat with SRSS versus firm surface. For mGC, exercise and interaction effects were significant, with greater activation during single-leg stance while wearing SRSS. No significant SRSS-related increases were observed during forward or side lunges.
Conclusion: In healthy adults, the SRSS increases ankle muscle activation primarily during single-limb tasks, supporting potential use for balance and ankle-stabilization training.

Keywords: chronic ankle instability, ankle muscle activation, balance training, electromyography

Introduction

Ankle sprains are among the most common musculoskeletal injuries in athletic, military, and general populations. Lateral ankle sprains account for most ankle ligament injuries and commonly involve the anterior talofibular ligament, calcaneofibular ligament, and, less frequently, the posterior talofibular ligament.[1–4] Although many individuals recover quickly after an acute ankle sprain, a substantial proportion report persistent pain, swelling, recurrent sprains, instability, or a sensation of the ankle "giving way."[1,3,5] These residual symptoms may contribute to chronic ankle instability (CAI), a condition associated with impaired proprioception, altered neuromuscular control, strength deficits, reduced postural control, and increased risk of reinjury.[5–8]

CAI is commonly described as having mechanical and functional components. Mechanical instability refers to pathologic ligamentous laxity or structural insufficiency, whereas functional instability refers to recurrent symptoms of instability or giving way in the absence of measurable ligamentous laxity.[5,6] Contemporary models of CAI recognize that these components frequently overlap and may include sensorimotor, mechanical, psychological, and motor-behavioral impairments.[6,7] Deficits in afferent feedback from ligamentous, capsular, musculotendinous, and cutaneous receptors may alter reflexive muscle activation and postural control after ankle injury.[6,8] Even after ligament healing, impaired neuromuscular control may persist and contribute to recurrent sprains.[5–8]

Rehabilitation after ankle sprain commonly includes progressive loading, strengthening, balance training, perturbation training, and sport- or activity-specific functional retraining.[3,9,10] Strengthening of the ankle evertors, dorsiflexors, plantar flexors, and intrinsic stabilizers is important because these muscles contribute to dynamic ankle stability during walking, running, cutting, landing, and single-limb support.[9–11] The fibularis longus and brevis are particularly important during inversion perturbations because they assist in resisting excessive inversion and contribute to lateral ankle stability.[6,11] The tibialis anterior contributes to ankle dorsiflexion, inversion control, and co-contraction around the ankle complex, whereas the gastrocnemius assists with plantar flexion control and postural stability during weight-bearing tasks.

Balance and postural-control training are also well-supported interventions after ankle sprain and in individuals with CAI.[3,9,12,13] Balance training may improve sensorimotor control by challenging integration of visual, vestibular, and somatosensory information.[12,13] Clinical programs often use firm-surface single-limb tasks, squats, lunges, wobble boards, foam pads, BOSU trainers, disks, and other unstable or compliant surfaces. These devices are intended to increase neuromuscular demand and promote dynamic stabilization of the ankle and lower extremity.

The StepRight Stability System (SRSS) is a shoe-mounted balance device designed to create an unstable interface between the shoe and floor (Figure 1). The device includes two inflatable hemispheres attached to the plantar aspect of the shoe; inflation can be modified to adjust task difficulty. Because the SRSS moves with the user, it may challenge balance differently than stationary balance platforms. However, limited objective evidence exists regarding whether the SRSS increases ankle muscle activation during common rehabilitation exercises.

The purpose of this study was to quantify and compare activation of the fibularis longus (FL), tibialis anterior (TA), and medial gastrocnemius (mGC) during four exercises performed on a firm surface while wearing athletic shoes and while wearing the SRSS. It was hypothesized that exercises performed with the SRSS would elicit greater muscle activation than the same exercises performed on a firm surface.

Figure 1. StepRight Stability System footwear.

Methods

Participants

Twenty healthy adults volunteered to participate. The sample included 10 women and 10 men. Female participants had a mean ± SD age of 23.9 ± 0.57 years, body mass of 161.8 ± 34.61 lbs., and height of 65.5 ± 3.13 in. Male participants had a mean ± SD age of 25.0 ± 1.49 years, body mass of 185.7 ± 22.02 lbs., and height of 72.3 ± 1.94 in. Participants were recruited through social media and word of mouth.

Inclusion criteria required no lower-extremity injury within the previous year and no known balance impairment. Two datasets were identified as outliers and were excluded from final analysis when appropriate. The Institutional Review Board of Central Michigan University approved the study, and all participants provided written informed consent.

Electromyography Preparation

Surface electromyography (EMG) was used to record activity of the FL, TA, and mGC of the dominant limb using Norotrode surface electrodes with a 1-cm interelectrode distance and a Motion Lab Systems MA300 EMG system (Motion Lab Systems, Baton Rouge, Louisiana). Signals were sampled at 1200 Hz.

Electrode placement followed published surface EMG recommendations.[14,15] For the FL, electrodes were placed one-third of the distance from the fibular head to the lateral malleolus. For the TA, electrodes were placed one-third of the distance from the fibular head to the medial malleolus. For the mGC, electrodes were placed over the medial muscle belly. The skin was cleaned with an electrode preparation pad before electrode placement. Electrodes were secured with tape and elastic wrap to reduce movement artifact during testing.

Maximum Voluntary Isometric Contractions

Maximum voluntary isometric contractions (MVICs) were recorded for normalization. For the TA, participants sat at the edge of a treatment table while the examiner manually resisted combined ankle dorsiflexion and inversion. For the FL, participants were positioned side lying while the examiner placed the foot into plantar flexion and resisted eversion. For the mGC, participants lay prone with both feet slightly off the table. A wedge was placed against the wall at the level of the foot to standardize slight plantar flexion, and the participant performed a maximal plantar-flexion contraction while the examiner stabilized the participant and table.[16] For each muscle, participants completed three 5-second MVIC trials with 15 seconds of rest between trials. Standardized verbal encouragement was provided during all MVIC trials.

Exercise Conditions

Participants performed four exercises under two surface conditions: athletic shoes on a firm surface (Firm Surface) and athletic shoes with the SRSS (SRSS) attached to the dominant foot. The four exercises were single-leg stance, single-leg squat, forward lunge, and side lunge. Condition order and exercise order were randomized. Dominant limb was determined by asking participants which leg they would use to kick a ball.

Before data collection, an examiner demonstrated each exercise, and participants were allowed practice trials until they were comfortable with the task. During the forward and side lunges, participants stepped with the dominant limb and maintained approximately 60° of knee flexion. Participants were instructed to keep the trunk upright, shift body weight over the dominant limb, and keep the contralateral heel on the ground. During single-leg stance, participants stood on the dominant limb with the knee near full extension and the opposite knee flexed. During the single-leg squat, participants squatted on the dominant limb to approximately 45° of knee flexion. For all exercises, participants crossed their arms over the chest and focused on a fixed point. Knee angle was monitored with a goniometer.

Testing Procedures

For each exercise and condition, participants completed three 15-second trials. The first 5 seconds allowed the participant to assume the test position, EMG data were collected during the middle 5 seconds, and the final 5 seconds were maintained to reduce signal drop-off or premature relaxation. Participants rested for 2 minutes between trials and exercises. If a participant lost balance or failed to maintain the required position, the trial was stopped and repeated.

EMG Signal Processing

Raw MVIC and exercise EMG data were processed using Motion Lab Systems software. A 60-Hz notch filter and 20- to 450-Hz band-pass filter were applied. For each MVIC, the middle 5-second window was analyzed. Five maximal peaks were selected and averaged to determine peak MVIC for each muscle. Exercise EMG data were normalized to the corresponding muscle MVIC and expressed as a percentage of MVIC.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 23 (IBM Corp, Armonk, New York). Distributions were assessed for normality. Variables that were not normally distributed were transformed using the log10 function and reassessed. No significant sex differences were identified. Reliability was examined using intraclass correlation coefficients [$ICC_{(3,1)}$]. Separate 2 × 4 repeated-measures analyses of variance were conducted for each muscle to examine the effects of surface condition and exercise. When significant effects were identified, paired-samples *t* tests were used for post hoc comparisons. Statistical significance was set at $p < .05$.

Results

Means ± SD of MVIC for muscles during performing balance activities with SRSS versus Firm Surface are presented in Table 1. $ICC_{(3,1)}$ single-measure values ranged from 0.192 to 0.915, and average-measure values ranged from 0.416 to 0.970. All single- and average-measure ICCs were statistically significant except for FL and mGC activity during the side lunge on the firm surface.

For the FL, significant main effects were found for exercise ($F_{(3,57)} = 83.63$, $p < .001$) and surface condition ($F_{(1,19)} = 63.05$, $p < .001$). A significant surface-by-exercise interaction was also present ($F_{(3,57)} = 31.60$, $p < .001$). Post hoc testing showed significantly greater FL activation during single-leg stance and single-leg squat while wearing the SRSS compared with the firm-surface condition ($p < .001$).

For the TA, significant main effects were found for exercise ($F_{(3,57)} = 22.340$, $p < .001$) and surface condition ($F_{(1,19)} = 37.70$, $p < .001$). A significant surface-by-exercise interaction was also identified ($F_{(3,57)} = 19.04$, $p < .001$). Post hoc testing demonstrated significantly greater TA activation during single-leg stance and single-leg squat while wearing the SRSS compared with the firm-surface condition ($p < .001$).

For the mGC, the main effect of exercise was significant ($F_{(3,57)} = 69.722$, $p < .001$). A significant surface-by-exercise interaction was also found ($F_{(3,57)} = 9.43$, $p < .001$). Post hoc testing demonstrated significantly greater mGC activation during single-leg stance while wearing the SRSS compared with the firm-surface condition.

Table 1. Mean±SD of MVIC for muscles during performing balance activities with SRSS versus Firm Surface.

	FL		**TA**		**mGC**	
MVIC (%)	**SRSS**	**Firm Surface**	**SRSS**	**Firm Surface**	**SRSS**	**Firm Surface**
Forward Lunge	15.95±7.71	15.16±5.02	13.34±11.16	9.68±6.36	6.06±5.58	7.62±6.78
Side Lunge	17.04±16.09	9.22±7.33	18.53±16.83	18.54±18.37	3.41±2.71	3.37±2.09
Stance	58.25±13.53	28.38±8.66	42.52±17.07	15.81±7.96	33.73±12.62	26.12±9.67
Single Leg Squat	45.91±12.31	27.52±9.58	39.52±12.40	20.85±10.57	17.34±7.22	12.04±11.07

Discussion

The purpose of this study was to determine whether the SRSS increased activation of selected ankle muscles during common rehabilitation exercises. The hypothesis was partially supported. The SRSS increased FL and TA activation during single-leg stance and single-leg squat and increased mGC activation during single-leg stance. However, the SRSS did not significantly increase activation during forward or side lunges.

These findings suggest that the SRSS may be most effective when the entire body mass is supported by the limb wearing the device. During single-limb tasks, the unstable interface created by the SRSS likely increased frontal- and sagittal-plane demands at the ankle, requiring greater activation of the FL, TA, and mGC to maintain posture. In contrast, during forward and side lunges, the contralateral limb remained on a firm surface and likely contributed substantially to balance and load sharing. Because the SRSS was worn only on the lead limb, the total balance challenge may have been insufficient to produce a significant increase in ankle muscle activation during double-limb tasks.

The increased FL activation observed during single-limb tasks is clinically relevant because the fibularis muscles are important dynamic stabilizers of the lateral ankle. Delayed or reduced fibularis activation has been described in individuals with CAI, and rehabilitation programs frequently emphasize exercises that improve ankle evertor strength and neuromuscular responsiveness.[6,9,11] Increased TA activation during SRSS single-limb tasks may also be beneficial because the TA contributes to ankle positioning, dorsiflexion control, and co-contraction strategies used during postural stabilization. Increased mGC activation during single-leg stance suggests that the SRSS may also challenge plantar-flexor control during static balance tasks.

The findings are consistent with previous research showing that balance and perturbation-based exercises can increase neuromuscular demand and improve sensorimotor outcomes after ankle injury.[12,13,17,18] Prior studies have demonstrated that single-limb balance tasks often produce greater ankle muscle activation than more stable or double-limb tasks.[17,19] The present findings extend this work by providing preliminary EMG evidence for a shoe-mounted unstable device. Unlike stationary devices such as wobble boards or BOSU trainers, the SRSS attaches directly to the shoe and may allow clinicians to progress from static single-limb tasks toward more functional stepping, lunging, or sport-specific movements.

For healthy adults, the SRSS appears to increase ankle muscle activation during single-limb stance and single-leg squat. Clinicians may consider using the SRSS as an adjunct to ankle rehabilitation or neuromuscular training when the goal is to increase ankle stabilizer demand. Based on these findings, SRSS use may be most appropriate during single-limb tasks rather than lunges performed with the opposite foot on a firm surface. Progression should be individualized and should consider patient symptoms, balance capacity, stage of healing, and movement quality. However, because this study included healthy participants, findings should not be generalized directly to patients with acute ankle sprain, CAI, vestibular disorders, or other balance impairments. In clinical populations, the SRSS may need to be introduced gradually, with external support available to reduce fall risk.

Strengths of this study included randomized exercise and condition order, standardized joint angles, consistent testing procedures, and electrode placement based on published EMG recommendations. The use of MVIC normalization allowed comparison across muscles and participants. Several limitations should be considered. First, the sample consisted of healthy young adults, not individuals with acute ankle sprain or CAI. Second, EMG was recorded during static holds, although many athletic and rehabilitation movements are dynamic. The first 5 seconds of each trial, during which participants moved into position, were not analyzed. Third, a few exercise trials produced activation values greater than MVIC, which may reflect limitations in manual MVIC testing, participant effort, or differences between isolated MVIC positions and functional weight-bearing tasks. Fourth, the SRSS was tested only on the dominant limb; bilateral SRSS use was not examined. Finally, the study assessed muscle activation but did not evaluate clinical outcomes such as balance performance, pain, recurrent sprain rate, perceived instability, or return-to-activity measures.

Future studies should examine the SRSS in individuals with CAI, recent ankle sprain, or other lower-extremity conditions. Dynamic tasks such as stepping, hopping, cutting, landing, and gait should be evaluated because the SRSS is designed to challenge balance during movement. Additional research should compare unilateral and bilateral SRSS use, examine different inflation levels, and determine whether increased EMG activation translates to improved clinical outcomes. Longitudinal intervention studies are needed to determine whether SRSS-assisted training improves postural control, strength, functional performance, perceived instability, and reinjury risk.

Conclusion

In healthy adults, the SRSS increased FL and TA activation during single-leg stance and single-leg squat and increased mGC activation during single-leg stance. No significant increases were observed during forward or side lunges. These findings suggest that the SRSS may be a useful adjunct for increasing ankle muscle activation during single-limb rehabilitation exercises. Further research is needed to determine its effectiveness in clinical populations and during dynamic functional tasks.

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