The Acute Effects of Local Vibration Therapy on Ankle Sprain and Hamstring Strain Injuries

Kimberly S. Peer, EdD, ATC, LAT; Jacob E. Barkley, PhD; Danielle M. Knapp, BS

Abstract: Aims: The purpose of this study was to determine if biomechanical muscle stimulation (BMS) applied directly to different segments of the body using the Swisswing® device results in acute improvements in range of motion and perceived stiffness in physically active adults with acute or subacute ankle sprain and hamstring strain injuries. Methods: Two separate groups of individuals with grade I or II ankle sprain (n = 5; 21.2 ± 1.9 years) or hamstring strain (Nn= 5; 20.6 ± 1.8 year) underwent 20 minutes of a controlled therapy consisting of ice, compression, and elevation, and 10 minutes of segmental BMS using the Swisswing® at 20 Hz. Ankle (dorsiflexion, plantar flexion, inversion, eversion), hamstring flexibility, and subjective ratings of stiffness were assessed prior to control treatment (baseline), post-control treatment, and post-Swisswing® treatment. Results: Relative to the post-control condition, Swisswing® treatment significantly (*P* < 0.03 for all) increased ankle dorsiflexion and eversion and hamstring flexibility, and significantly (*P* ≤ 0.05) decreased perceived ankle and hamstring stiffness. Conclusion: Segmental BMS therapy using the Swisswing® device appears to have significant acute benefits for improving flexibility and reducing perceived stiffness in healthy adults with ankle or hamstring injury. Future research is needed to determine the duration of these effects and if repeated periods of segmental BMS therapy aid in long-term injury recovery.

Keywords: biomechanical muscle stimulation; athletic injury; perceived stiffness; range of motion

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Introduction

Background Information

Biomechanical muscle stimulation (BMS) in a whole body vibration mode has been used as a therapeutic intervention that has demonstrated positive effects on muscle tissue.[1–4] This external stimulation to muscle tissue facilitates mechanical stretch of the muscle fibers similar to that of a maximal stretch by simulating biomechanical stressors.[5] Vibration therapy was later found to target the sensory and motor systems, depending on the application of the vibration and the potential parameters of the stimulatory device.

Evoking a tonic vibratory response (TVR) is the physiological mechanism of high-frequency BMS. Tonic vibratory response is a reflex that results from the stimulation of the muscle spindle, leading to a contraction of the muscle stimulated. Reciprocal inhibition during the treatment also causes depression of the antagonist muscle group, resulting in facilitation of a muscle stretch.[6] However, other researchers found that vibration may be used to increase tone or force of contraction of the agonist or decrease tone of the antagonist. The involvement of the stretch reflex as a physiologic foundation increased interest in the potential use of this innovative therapy as a therapeutic intervention.[2,3,7]

Previous research examining whole body BMS has demonstrated increased range of motion and flexibility,[1,8–10] decreased muscle stiffness,[9] increased recovery from musculoskeletal injury,[11,12] decreased pain,[13–15] reduction of fibromyalgia and Parkinson's disease symptoms,[16,17] and improvement in respiratory gas exchange in overweight and obese women.[18] Other claims have been made that whole body BMS therapy may impact a range of physiological functions[19] such as physical strength and power,[20,21] blood flow and peripheral lymphatic drainage,[22] bone density,[23] muscle activation,[24] neuromuscular recruitment patterns,[24,25] and body balance.[26,27]

Although there are commercially available BMS devices (Swisswing®) that are applied to specific segments of the body, there is presently no research examining the therapeutic impact of such devices.

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Segmental BMS using the Swisswing® differs from whole body BMS in several ways. Segmental BMS uses regional stimulation rather than whole body stimulation. Whole body stimulation relies on indirect effects on tissues rather than direct effects on localized tissue. Because segmental BMS can be applied directly to the affected area, lower stimulation loads may still be effective compared with those used in whole body vibration research. Lower stimulation loads may be more comfortable for a patient while still providing a therapeutic benefit.

The purpose of this study was to determine whether (after receiving a standard treatment of ice, compression, and elevation) segmental BMS muscle therapy increases range of motion and reduces perceived stiffness in physically active individuals with acute and subacute ankle sprains or hamstring strains. We hypothesized that using segmental BMS via the Swisswing® would increase post-therapy range of motion and decrease perceived stiffness in that particular injury site even after receiving a standard therapy of ice, compression, and elevation.

Materials and Methods

Participants

Two separate groups of individuals presenting with different soft tissue injuries (ankle sprain, hamstring strain) were studied (n = 10). Each group consisted of 5 participants with either first- or second-degree ankle sprain (n = 4 men, 1 women with ankle sprains) or hamstring strain (n = 3 men, 2 women with hamstring strains). Participants were recruited via direct contact through a research assistant working directly with a licensed athletic trainer at Kent State University. Participants were evaluated using standard evaluation techniques[28–31] to determine the grade of ankle and/or hamstring injury. Participants were required to be physically active (≥ 30 minutes of planned exercise, 4 times • week 1 for at least 1 month prior to injury), college-aged men or women who had been injured in the past 5 days. Participants were excluded if they exhibited any contraindications to BMS therapy such as joint prostheses, cardiac pacemakers, diabetic neuropathy, and cardiovascular and circulatory diseases. Written informed consent was obtained from each individual prior to participation. The study was approved by the Institutional Review Board at Kent State University.

Design

This study was a repeated measures design that evaluated objectively measured flexibility and subjective ratings of stiffness before and after 2 types of treatment: traditional (rest, ice, and compression) and BMS (Swisswing®). Each injury group was evaluated separately from the other as the objective measurements of flexibility (ankle: inversion, eversion, dorsiflexion, and plantar flexion versus a single measure of hamstring flexibility) were different and could not be compared.

Procedures

In order to determine if a volunteer's injury was severe enough (first- or second-degree injury) to be eligible for this study, injury assessments were performed by an experienced licensed athletic trainer using standardized orthopedic evaluation techniques for ankle and hamstring injuries, respectively, including history, visual inspection, palpation, joint and muscle functional assessment, joint stability tests, and special tests.[28–31] On completion of injury assessment, eligible participants were measured for height and weight using a balance beam scale (Detecto Industrial Scales of New York Inc., Broooklyn, NY) and a stadiometer (Detecto Industrial Scales of New York Inc., Broooklyn, NY). Following clinical diagnoses of the injury, baseline flexibility measurements using a universal goniometer were taken by 1 trained research assistant. Goniometry is proven to be the gold standard for clinical measurement of joint range of motion with well-established reliability and validity.[32–34] The measurements were performed as follows.

Ankle

Ankle dorsiflexion and plantar flexion: Patient is placed in a long sitting position off the edge of a table with the knee supported to maintain approximately 20° to 30° knee flexion. With the ankle at anatomical neutral, the universal goniometer is aligned with the axis inferior to the lateral malleolus, the stationary arm parallel with the long axis of the fibula, and the movable arm parallel to the midline of the calcaneus. Active dorsiflexion motion is measured. The patient is realigned as indicated, then active plantar flexion is measured.[23]

Ankle inversion and eversion: Patient is supine on the table, with the knee slightly flexed as described previously. The axis of the universal goniometer is aligned equidistance between the malleoli on the dorsal surface of the foot. The stationary arm is positioned on the crest of the tibia aligned with the tibial tuberosity, while the movable arm is aligned on the dor-

sal surface of the second metatarsal shaft. Active inversion is measured. The goniometer is realigned as indicated followed by active eversion of the subtalar joint.[31,34]

Hamstring

Hamstring flexibility: Range of motion was determined by assessing straight leg hip flexion. The participant was positioned supine on the table with the opposite lower limb flat on the table. The affected side is measured, with the axis of the universal goniometer placed at the lateral hip approximately a finger breadth anterior and superior to the femoral greater trochanter. The stationary arm was aligned with the long axis of the trunk, and the movable arm is placed along the lateral femoral shaft. Active straight-legged hip flexion is measured.[31,34]

Participants then rated their stiffness utilizing a 10-point Likert scale ranging from 0, not stiff at all, to 10, the most stiffness. After obtaining baseline flexibility and stiffness measurements, all participants completed the control treatment.

Ankle and Hamstring

Participants were treated in the athletic medical facility at the designated institution and were treated with crushed, bagged ice, which was applied directly to the skin of the injured site (ankle or hamstring) and secured in place with a 4-in elastic wrap using moderate tension, as gauged by the ability to insert 2 fingers under the wrap following application. The injured extremity was elevated with the hip flexed to approximately 45° for 20 minutes with the patient in a supine position.[29]

Following the control treatment for the hamstring and ankle injury participants, the ice and wrap were removed, and the appropriate goniometric measures were taken immediately after control treatment (≤ 2 minutes). Ankle ranges of motion were taken in the following order: dorsiflexion, plantar flexion, inversion, and eversion. Participants' perceived stiffness was then reassessed. After the post-control treatment assessment, BMS treatment using the Swisswing® was administered.

Ankle

Three BMS positions on the Swisswing® machine were used for 2 minutes each at 20 Hz: bottom of foot resting on the drum of the machine; heels resting on the drum of the machine; and gastrocnemius belly resting on the drum of the machine. One minute of rest was provided between each BMS position.

Hamstring

Four BMS positions on the Swisswing® machine were used for 2 minutes each at 20 Hz: standing gluteals (standing with buttocks resting on drum, standing hamstrings); standing with hamstring resting/draped over drum (right and left leg were performed separately); and seated gastrocnemius (seated with belly of the calf draped over the drum).

Following the Swisswing® BMS treatment for the hamstring and ankle injury participants, the appropriate goniometric measures were taken a final time immediately after treatment (≤ 2 minutes). Ankle ranges of motion were again taken in the following order: dorsiflexion, plantar flexion, inversion, and version. Participants' final perceived stiffness was then assessed.

Instruments

Stiffness Likert Scale

The Stiffness Scale used in this study was a modified 10-point Numeric Pain Scale[35,36] adjusted to indicate stiffness ranging from 0 (not stiff at all) to 10 (the most stiffness). These Likert scales are widely used in hospital systems and health care to rate pain and obtain subjective intensity ratings from the participant. The 10-point Likert scales are shown to be more reliable than the 5-point Likert scales.[37]

Swisswing®

The experimental instrument used in this study was the Swisswing®. Swisswing® is a BMS device manufactured by Swiss Therapeutic Training Products (Swiss TTP, Twinsburg, OH). This device comprises a padded drum that rotates at predetermined hertz level of 20 Hz for this study to provide BMS (via vibration) to the body tissue (Figure 1). The principle of stimulation with the Swisswing® is based on combined tension and rotation. This unique stimulation technique facilitates muscle stretching without compression of the targeted cells and tissue. The Swisswing® technology uses defined, circular movements with positive and negative acceleration to stimulate muscle tissue with amplitudes (1–6 mm) independent of frequency and load. The goal of BMS using the Swisswing® is to create a mechanical imitation of the physiological tremor due to external sinusoidal stimulation, causing longitudinal vibration of muscle fibers simulating vibratory stimulation about the muscles and tendons.[5] Although (according to the manufacturer) the Swisswing® is used extensively throughout the United States in fitness and athletic medical facilities, this study was the first to examine the efficacy of the Swisswing® on musculoskeletal injuries from a quantitative approach.

Figure 1. Swisswing® BMR 2000.

BMR 2000 technical specifications: weight: 136 lb; dimensions: 34" × 20" × 42"; electrical connection: 120V, 60 Hz, 1.5 kW max; frequency range: 6–35 Hz; amplitude 2 mm, 3 mm, or 4 mm (constant); cycle time: 2 minutes.

Data Analysis

A priori hypotheses were that hamstring and ankle flexibility would be greater after Swisswing® treatment than after control treatment. Therefore, statistical power was calculated using paired samples t-tests for differences in hamstring flexibility, ankle inversion, eversion, and dorsiflexion from post-control to post-Swisswing® treatment. Power analysis was not performed for plantar flexion because plantar flexion has the largest of the 4 ankle ranges of motion, and is least likely to be affected in ankle injury situations.[29,30] Participants with hamstring injuries exhibited a flexibility of 76.8° ± 13.7° before Swisswing® treatment and 86.2° ± 12.1° after treatment. This difference yielded an effect size of 5, which required 3 participants to achieve a power of ≥ 0.8 and an $\alpha \leq 0.05$. Participants with ankle injuries exhibited an inversion of 8° ± 0.7°, an eversion of 7° ± 1.8°, and a dorsiflexion of 39.6° ± 8.4° prior to Swisswing® treatment, and 11° ± 2.2°, 9.2° ± 1.6°, and 44.4° ± 8.9° after treatment, respectively. The differences of the 3 comparisons yielded effect sizes of 1.8 for inversion, 1.7 for eversion, and 10.9 for dorsiflexion. These effect sizes would require 2 to 5 participants to achieve a power of ≥ 0.8 and an $\alpha \leq 0.05$. Based on the observed differences for these measures of flexibility for the hamstring and ankle injury assessments, the present sample size (N = 5 per injury group) was deemed to be sufficient.

One-way analyses of variance (ANOVA) with repeated measures on time of assessment (baseline, post-control, post-Swisswing®) were used to examine differences in assessments of flexibility for both the ankle and hamstring. Although there was only a single measure of flexibility for the hamstring, each of the 4 measures of flexibility for the ankle (eversion, inversion, dorsiflexion, and plantar flexion) were assessed. Post hoc analyses of any significant main effects were performed using paired sample t-tests with the Benjamini and Hochberg False Discovery Rate correction.[38] Multiple Wilcoxon signed-rank tests were used to assess changes in perceived hamstring and ankle stiffness from baseline to post-control, from baseline to post-treatment, and from post-control to post-treatment. The Benjamini and Hochberg False Discovery Rate correction was also applied to the *P* values from the multiple comparisons of perceived stiffness.

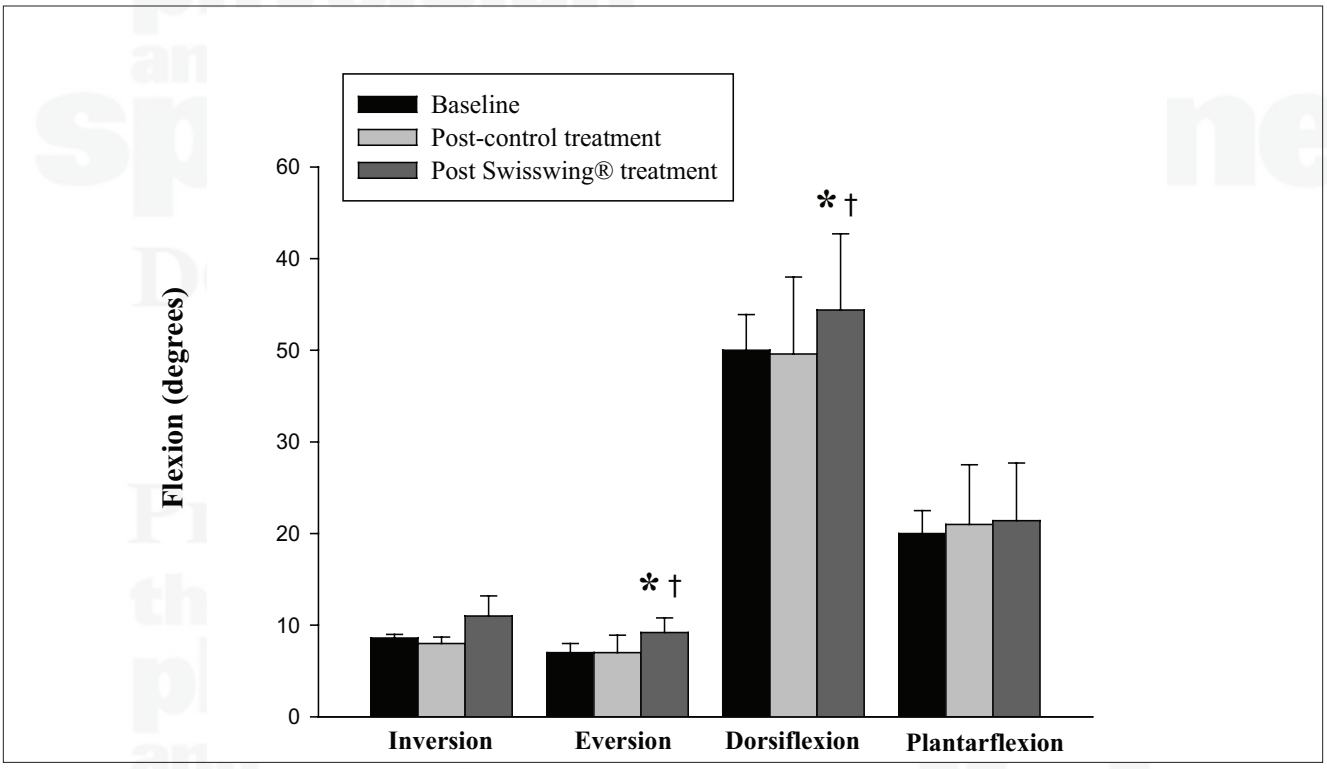
Results

Physical characteristics for participants with ankle injuries and those with hamstring injuries are shown in Table 1. Figure 2 illustrates baseline, post-control, and post-Swisswing® treatment ankle flexibility (eversion, inversion, dorsiflexion, and plantar flexion). There were significant main effects of time of assessment for eversion ($P = 0.002$), dorsiflexion ($P < 0.001$), and inversion ($P = 0.03$), but not plantar flexion ($P = 0.7$). Post hoc analysis of the main effects of time of assessment for eversion and dorsiflexion demonstrated significantly greater ($P = 0.03$ eversion; $P = 0.0002$ dorsiflexion) flexibility post-Swisswing® treatment (9.2° ± 1.6° eversion; 44.4° ± 8.3° dorsiflexion) versus post-control treatment (7° ± 1.9° eversion; 39.6° ± 8.4° dorsiflexion) and significantly greater ($P = 0.02$ eversion; $P = 0.004$ dorsiflexion) flexibility post-Swisswing® treatment versus baseline (7° ± 2.1° eversion, 40° ± 8.7° dorsiflexion). Post hoc analysis of the main effect of inversion demonstrated

Table 1. Participant characteristics

	Ankle (N = 5; 4 men, 1 woman)	Hamstring (N = 5; 3 men, 2 women)
Age (y)	21.2 ± 1.9	20.6 ± 1.8
Height (m)	1.8 ± 0.1	1.8 ± 0.1
Weight (kg)	93.9 ± 24.3	83.0 ± 16.7

Figure 2. Ankle inversion, eversion, dorsiflexion, and plantar flexion (in degrees) at baseline, post-control, and post-Swisswing® treatment.



*Paired samples T-test demonstrates a significant increase ($P < 0.03$) in ankle flexibility post-Swisswing® treatment versus post-control treatment.
†Paired samples T-test demonstrates a significant increase ($P < 0.02$) in ankle flexibility post-Swisswing® treatment versus baseline.

a trend ($P = 0.07$) toward a difference in ankle inversion from the post-control (8° ± 0.7°) to the post-Swisswing® (11° ± 2.2°) conditions. There were no additional differences in any measure of ankle flexibility ($P \geq 0.09$).

Figure 3 illustrates baseline, post-control, and post-Swisswing® treatment ankle stiffness, as indicated via a 10-point Likert scale. Wilcoxon signed-rank tests revealed that perceived stiffness was significantly ($P = 0.05$ for both) reduced post-Swisswing® treatment (4.8 ± 0.4) versus post-control treatment (6.4 ± 1.4) and baseline (6.8 ± 1.3). Baseline and post-control treatment ankle stiffness were not significantly different ($P = 0.32$).

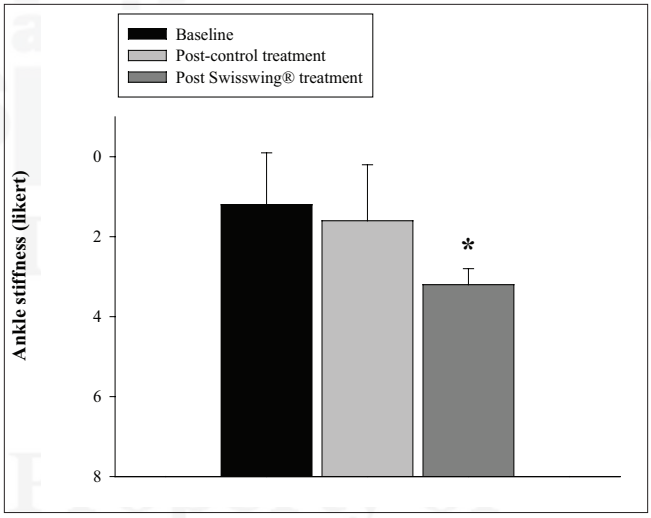
Figure 4 illustrates baseline, post-control, and post-Swisswing® treatment hamstring flexibility. There was a significant main effect of time of assessment ($P = 0.015$). This main effect of time of assessment was due to a significantly greater ($P = 0.0002$) flexibility post-Swisswing® treatment (86.2° ± 12.1°) versus post-control treatment (76.8° ± 13.7°). Baseline hamstring flexibility (80.4° ± 16.6°) was not significantly different than either post-control treatment ($P = 0.24$) or post-Swisswing® treatment ($P = 0.19$).

Figure 5 illustrates baseline, post-control, and post-Swisswing® treatment hamstring stiffness, as indicated via a 10-point Likert scale. Wilcoxon signed-rank tests revealed that perceived stiffness was significantly ($P = 0.05$) reduced post-Swisswing® treatment (4.8 ± 1.5) versus post-control treatment (7 ± 1.6). There was a trend ($P = 0.06$) toward a greater perceived stiffness at baseline (6.6 ± 1.3) versus post-Swisswing® treatment. Baseline and post-control treatment hamstring stiffness were not significantly different ($P = 0.16$).

Discussion

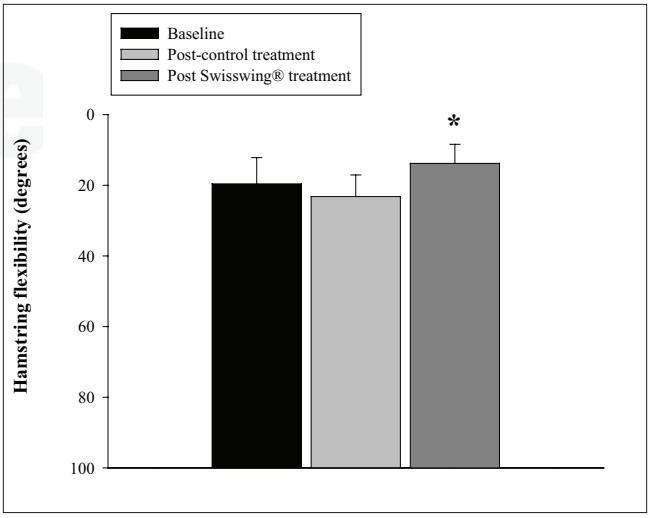
Segmental BMS using the Swisswing® significantly improved acute ankle and hamstring flexibility and perceived stiffness relative to a control treatment of ice, compression, and elevation in physically active adults. This was the first study we are aware of that assessed the effectiveness of segmental BMS using the Swisswing® on measures of flexibility and perceived stiffness. Previously, whole body BMS has been shown to positively affect muscle stiffness,[9,10] flexibility,[1,8,9] and pain.[13–15] However, because whole body BMS requires a patient to stand on the

Figure 3. Ankle stiffness (assessed with a Likert scale) at baseline, post-control, and post-Swisswing® treatment.



*Wilcoxon signed-rank tests demonstrate that reported stiffness post-Swisswing® treatment was significantly (P = 0.05) less than postcontrol treatment and at baseline.

Figure 4. Hamstring flexibility (in degrees) at baseline, post-control and post-Swisswing® treatment.



*Paired samples T-test demonstrates a significant increase (P = 0.0002) in measured hamstring flexibility post-Swisswing® treatment versus postcontrol treatment.

apparatus, it is not a viable intervention for patients who have difficulties standing. Conversely, segmental BMS is applied directly to or near the area of injury, making it possible for the patient to receive treatment while seated or supine. Even if a patient is capable of safely standing during whole body BMS, the therapy can be uncomfortable because the entire body is affected with lower amplitudes and frequencies. This may lead to dizziness, disorientation, and nausea.[9] Because the entire body is not shaken with segmental BMS and a lower vibration frequency is used (20 Hz segmental vs 30–50 Hz whole body), this is less likely to occur. None of the participants examined reported any negative side effects of treatment with segmental BMS on the Swisswing®.

Biomechanical muscle stimulation is believed to alter the tone of the agonist and antagonist muscle groups in the affected area, creating an environment that is more conducive to stretch.[6] It has been postulated that this effect occurs via the muscle spindle.[2,3,6,7] A combination of altered muscle tone and potentially decreased pain perception could contribute to the increased range of motion evidenced after treatment.

Because segmental BMS is applied directly to the affected area, its impact is likely more concentrated than whole body BMS. This may trigger a greater response in the affected muscle, including contractility of the agonist and relaxation of the antagonist, facilitating range of motion than whole body BMS. This would be especially true for injuries to the upper extremities, which are far removed from the vibratory source during whole body BMS, but could receive direct stimulation if using segmental BMS. Future investigations should seek to compare the acute effects of segmental BMS to whole body BMS on both upper and lower extremity injuries.

Although these results are intriguing, there are some limitations to this study. First, the number of participants studied in both the hamstring and ankle injury groups was small (N = 5 per group). Despite this small sample size, the magnitude of the changes in perceived stiffness and flexibility were great enough to provide for adequate statistical power to test for differences in most of these dependent variables with the present sample size. However, differences in ankle inversion between post-control and post-Swisswing® treatments only demonstrated a trend toward significance after the P values were corrected for multiple comparisons. If additional participants were used, this trend towards significance would likely become significant. In addition to demonstrating significant statistical power for all but one of the dependent variables hypothesized to be affected by BMS, it is important to note that after segmental BMS treatment, every participant relative to the post-control treatment assessment exhibited an improvement in the following variables: hamstring flexibility and perceived stiffness, and ankle inversion, eversion, dorsiflexion, and per-

ceived stiffness. Because of the universally positive changes in all measured variables other than plantar flexion, it is unlikely that examining additional participants would have significantly altered the current findings. However, to make comparisons between genders, age groups, injury severity, or other factors that may be differentially affected by segmental BMS using Swisswing®, examining a greater number of participants would be necessary.

Another potential limitation was the lack of counterbalancing of the order of treatments. This was done by design, as we rightly hypothesized that any changes associated with the control treatment would be smaller than the changes associated with BMS Swisswing® treatment. If the control treatment was to be performed after the Swisswing® treatment, the improvements noted may have hidden any potential fluctuations associated with the control treatment. However, future research should consider performing control treatment and Swisswing® treatment on separate days. This would allow for counterbalancing while not "burying" any fluctuations associated with the control treatment under the greater changes that appear to be associated with Swisswing® treatment.

Finally, the effects of segmental BMS Swisswing® treatment were only evaluated immediately after a single treatment. This study did not assess if these effects were temporary or if they aid in the healing process. Future research is recommended to assess how long these positive effects last after a single treatment and what the impact of repeated Swisswing® treatment has on the time for injury recovery. Chronic effects of segmental BMS Swisswing® treatment could provide valuable insights into injury management.

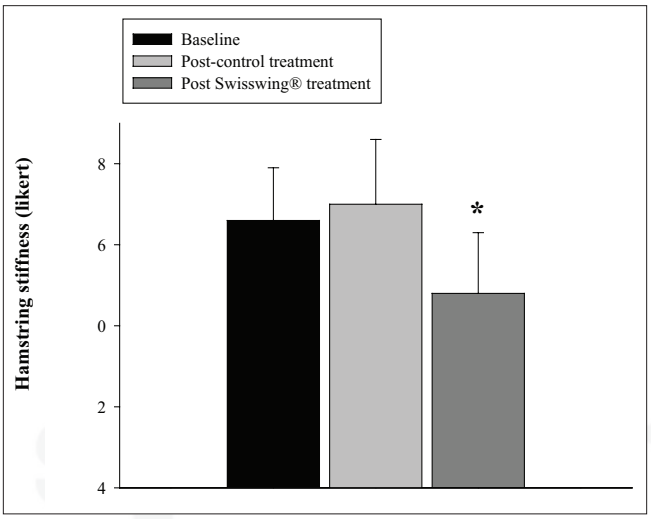
Conclusion

The present data support a significant, positive, acute impact of segmental BMS using the Swisswing® after receiving a control treatment of ice, compression, and elevation in participants with select hamstring and ankle injuries. Although there is evidence supporting the effectiveness of the use of whole body BMS on measures a variety of physiological and biomechanical functions,[1–4, 8–27] the present investigation is the first to assess the acute effects of segmental BMS on flexibility and perceived stiffness. The present results are supportive of the use of segmental BMS using the Swisswing®, but only in an acute setting. Further research on the repeated use of segmental BMS using the Swisswing® and its ability to enhance the recovery process is needed. However, the acute effects of this treatment on flexibility and stiffness for specific athletic injuries demonstrate potential as a therapeutic intervention.

Conflict of Interest Statement

Kimberly S. Peer, EdD, ATC, LAT, Jacob E. Barkley, PhD, and Danielle M. Knapp, BS disclose no conflicts of interest.

Figure 5. Hamstring stiffness (assessed with Likert scale) at baseline, post-control, and post-Swisswing® treatment.



*Wilcoxon signed-rank tests demonstrate that reported stiffness post-Swisswing® treatment was significantly (P = 0.05) less than post-control treatment.

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