

Acute Effects of Local Vibration With Biomechanical Muscle Stimulation on Low-Back Flexibility and Perceived Stiffness

Lee Anne Siegmund, PhD; Jacob E. Barkley, PhD; Danielle Knapp, MA; and Kimberly S. Peer, EdD, ATC, FNATA

■ ABSTRACT

This study investigated the effects of biomechanical muscle stimulation (BMS) on low-back and hamstring flexibility and perceived low back stiffness. Three healthy populations were examined: college-aged nonathletes, college-aged athletes, and physically active older adults. Low-back stiffness was reported using a stiffness Likert scale and range of motion was measured using the sit-and-reach test. Each group received BMS treatment and was retested. The college-aged nonathletes completed a control (no BMS treatment) condition on a separate day. Significant improvement ($P < .001$) in sit-and-reach performance after treatment in all treatment groups was noted (pre-BMS, 27.8 ± 10.6 cm; post-BMS treatment, 30.1 ± 10.4 cm). Average perceived stiffness decreased ($P = .01$) in all groups after undergoing treatment (pre-BMS, 5.0 ± 2.4 ; post-BMS, 3.2 ± 2.1). Perceived stiffness did not change ($P = .7$) in the control condition for the nonathlete group (precontrol, 5.3 ± 2.2 ; postcontrol, 5.2 ± 2.0). [*Athletic Training & Sports Health Care*. 2014;6(x):xxx-xxx.]

Low-back flexibility is often related to function, as well as to physical performance. Many athletes, including golfers, figure skaters, gymnasts, and hockey players experience low-back pain related to decreased flexibility.^{1,2} Research has discovered that limitations in spinal extension are predictive of future back pain in athletes.^{1,2} Low-back and hamstring flexibility has also been shown to be valuable for athletic performance requiring lower-body power.³ In addition to improved performance, improvements in low-back and hamstring flexibility have been associated with a reduction in back pain in some athletes.⁴⁻⁷ Older adults may also benefit from improvement in low-back flexibility,⁸ as limited flexibility of any part of the body has the potential to affect independent living for the older individual.⁹⁻¹¹

Whole-body vibration (WBV), in which the individual stands or sits on a vibrating platform, is believed to have multiple therapeutic effects. During WBV therapy, the vibratory stimulus likely causes muscles to contract and their antagonists to relax through the tonic vibratory response. It has been suggested that the vibration of the agonist muscle group stimulates the muscle spindle, resulting in a contraction.¹² Reciprocal inhibition, which enables relaxation of the antagonist muscle group and then enables muscle stretch, may lead to greater flexibility.¹² Although increased flexibility and reduced perceived stiffness^{13,14} have been identified as potential benefits of WBV, there is evidence of additional benefits, for which the mechanism is even less well understood. These benefits include improvements in muscle activation,¹⁵ balance,^{16,17} muscular strength,¹⁸⁻²⁵ blood flow, and lymph drainage.^{26,27} In addition, WBV has been shown to partially alleviate the symptoms associated with Parkinson's disease and fibromyalgia.^{28,29} Although the use of WBV has been

Dr Siegmund is from the Department of Exercise Physiology, The Cleveland Clinic, Cleveland; Dr Barkley is from the Department of Exercise Science, and Ms Knapp and Dr Peer are from the Department of Athletic Training, Kent State University, Kent, Ohio.

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Address correspondence to Kimberly S. Peer, EdD, ATC, FNATA, Kent State University, Department of Athletic Training, 350 Midway Drive, 266B MACC Annex, PO Box 5190, Kent, OH 44242; e-mail: kpeer@kent.edu.

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TABLE 1

VARIABLE	Study Participant Characteristics					
	COLLEGE-AGED NONATHLETES		COLLEGE-AGED ATHLETES		OLDER ADULTS	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
Sex (n)	6	13	3	7	9	6
Age (mean \pm SD) (y)	22.8 \pm 2.0	23.1 \pm 1.4	19.7 \pm 0.5	19.4 \pm 1.1	76.8 \pm 7.0	73.3 \pm 10.2
Height (mean \pm SD) (cm)	174.0 \pm 5.6	169.9 \pm 5.5	170.0 \pm 11.4	160.4 \pm 2.1	172.6 \pm 7.6	161.8 \pm 5.9
Weight (mean \pm SD) (kg)	74.0 \pm 15.3	66.7 \pm 8.8	77.0 \pm 30.0	52.4 \pm 3.3	79.9 \pm 7.4	66.0 \pm 4.2

shown to have multiple therapeutic uses, it has also been associated with side effects such as nausea, headache, vertigo, spinal instability, and disorientation.^{30,31}

Although WBV is widely researched, regionally applied segmental vibration—or biomechanical stimulation (BMS)—devices may provide similar therapeutic benefits without the limitations. In some cases of low-back stiffness, treatment with WBV may not be feasible due to the pain or weakness associated with certain body positions. Fundamentally, lack of flexibility in the lower back can affect spinal mechanics in many patient populations, directly leading to low-back pain.³²⁻³⁴ Because a segmental BMS device does not require an individual to stand and balance on a platform, this approach may be beneficial for populations with muscle weakness, movement disorders, or orthopedic limitations,³⁵ as it can be applied directly to the affected area, thereby limiting the overall vibratory response to the entire body. Several studies have examined different types of segmental vibration techniques to improve flexibility or function. Biomechanical muscle stimulation has been successfully used to increase shoulder range of motion for baseball pitchers, increase ankle range of motion, reduce foot drop in elderly stroke patients, improve hamstring flexibility, and enhance gymnasts' ability to perform splits.³⁵⁻³⁹

The purpose of the current study was to examine the effects of segmental BMS on low-back and hamstring flexibility and perceived stiffness across groups of healthy participants: in-season, college-aged (18 to 21 years) athletes; physically active, college-aged (20 to 24 years) nonathletes; and physically active older adults (aged \geq 61 years). Low-back and hamstring flexibility and perceived stiffness were also assessed in the college-aged nonathletes during a control condition (no BMS therapy) on a separate day. The authors hypothesized that segmental vibration treatment with

BMS would increase low-back and hamstring flexibility and reduce perceived stiffness in all 3 groups of participants and that there would be no change in flexibility and stiffness for college-aged nonathletes during the control condition.

METHOD

Participants

Three groups of participants were included in this study: college-aged athletes ($n = 10$); physically active, college-aged nonathletes ($n = 19$); and physically active older adults ($n = 15$). **Table 1** presents the study participants' characteristics. All participants ($N = 44$; 26 women, 18 men) were recruited via direct contact with research staff through flyers and presentations to the targeted groups seeking individuals with self-reported low-back stiffness. Stiffness was described to participants as a noticeable tightness (not pain) in the lower back while performing activities of daily living. No minimal level of self-reported threshold for low-back stiffness was included. Apart from self-reported low-back stiffness, none of the participants had recent back injury (diagnosis of recent injury or treatment for low-back injury within the past year) or any activity-limiting back pain. College-aged athletes were required to be enrolled at a National Collegiate Athletic Association (NCAA) Division 1 university as an intercollegiate athlete. College-aged nonathletes were required to be physically active at least 3 times per week, and the older adults were required to be aged \geq 61 years and registered as participants in an organized older adult exercise program sponsored by an NCAA Division 1 university. These participants had no low-back pathology, no documented disability, and were not receiving medical intervention for an existing low-back condition at the time of the study. Prior to enrolling, each participant was advised of the procedures associated with the study,

and each read and signed the informed consent forms. Participants were excluded from the study if they experienced any condition indicated as a contraindication to BMS therapy, including joint prostheses and implants located in the hip or spinal region, pregnancy, cardiac pacemakers, diabetic neuropathy, current back injury, and cardiovascular and circulatory diseases. Current back injury for this study was defined as a condition of the spine under which current or ongoing medical treatment is provided by a licensed health care provider. The study was approved by the university institutional review board.

Design

The current study utilized a 3-group (college-aged athletes, college-aged nonathletes, and older adults) by 2-time point (pre- and post-BMS treatment) mixed-method design, with time point as a within-participants variable. All participants were assessed for flexibility and perceived stiffness immediately before (pre-) and after (post-) BMS treatment. In addition to undergoing BMS treatment, the college-aged nonathletes completed a control condition on a separate day, during which their flexibility and perceived stiffness were assessed before (pre-) and after (post-) 10 minutes of seated rest. The order of the BMS treatment and control conditions was randomized, using a simple randomization technique of letters A (control) or B (BMS treatment), across the college-aged nonathletes.

Procedures

After providing informed consent, the participants completed an intake form, consisting of demographic and contact information. Participants completed an additional section that screened for exclusion criteria. While standing, and prior to completing any activity, including sit-and-reach measurements, each participant was asked to indicate his or her perceived stiffness with the Stiffness Scale, which consists of numeric and verbal descriptors that range from 0 = *not stiff at all* to 10 = *the most stiffness*.⁴⁰⁻⁴² Baseline sit-and-reach measurements, using the Figure Finder Flex-Tester (Novel Products Inc, Rockton, Illinois), were taken (in centimeters), using the device's Scale 4 protocol. One trained research assistant (D.K.) performed all participants' measurements. The specific measurements for low-back and hamstring flexibility were performed as follows: Each participant sat on the floor with his or her legs fully ex-

tended and the plantar surface of the feet resting on the vertical surface of the sit-and-reach device. The participants were instructed to reach forward with extended arms to contact the measuring tool on the top of the sit-and-reach device, thereby moving it to its furthest mark as they flexed their spine. Measurements were taken 3 consecutive times for each participant and were recorded in centimeters. The average value of these 3 trials was recorded.

The treatment protocol consisted of the following BMS positions on the Swisswing segmental BMS device (Swiss Therapeutic Training Products, Twinsburg, Ohio) for two minutes each at 20 Hz: The low-back BMS positions were standing gluteals (in which the participant leans with the buttocks pressing on the padded surface of the BMS drum), standing hamstrings (in which participants leaned against the machine with the belly of the hamstrings resting on the drum), standing and seated lower back (in which participants leaned against the drum of the BMS with the left and right lower back musculature [erector spinae group, collectively] resting against the drum). This procedure was then repeated with the participant seated on a stool that was positioned to the appropriate height to contact the desired musculature. One minute of rest was provided between each BMS position, for a total BMS treatment time of 11 minutes per participant. Immediately following treatment, the participant completed the final posttest Perceived Stiffness Scale and the post sit-and-reach test exactly as he or she had done prior to treatment. The same procedures were followed for the control group (college-aged nonathletes) during the control condition. However, during the control condition, the college-aged nonathletes did not undergo BMS but rather rested in a seated position for 10 minutes between the pretest and posttest. This control condition for the college-aged nonathletes occurred on a day separate from the treatment condition, and the order of the BMS treatment and control condition was randomized using a simple randomization technique.

Instruments

Stiffness Likert Scale. The Stiffness Scale used in this study was a modified 10-point Numeric Pain Scale,⁴⁰⁻⁴² which was adjusted to indicate stiffness ranging from 0 = *not stiff at all* to 10 = *the most stiffness*.

Biomechanical Muscle Stimulation. The experimental instrument used in this study was the Swiss-

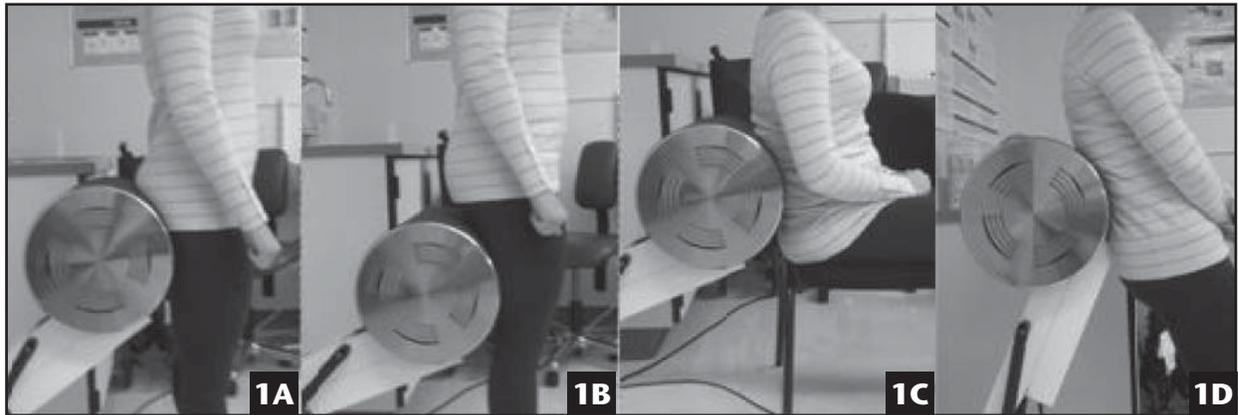


Figure 1. Biomechanical muscle stimulation treatment positions of the BMR 2000 [Swiss Therapeutic Training Products, Twinsburg, Ohio] are (A) standing treatment to buttocks, (B) standing treatment to hamstrings, (C) seated treatment to lower back, and (D) standing treatment to lower back. (Technical specifications can be accessed at <http://www.swissttp.com>).

wing, a US Food and Drug Administration-approved BMS device. This device consists of a padded drum that rotates at predetermined frequency (20 Hz for the current study) to provide BMS (via vibration) to the body tissue (Figure 1).

DATA ANALYSIS

All data were analyzed using SPSS version 17.0 (IBM Corp, Armonk, New York) with an a priori α level of $\leq .05$. A 3-group (college-aged nonathletes, college-aged athletes, older adults) \times 2-time point (pre- and posttreatment) analysis of variance (ANOVA) with repeated measures on time point was utilized to examine differences in sit-and-reach performance. An additional 2-condition (BMS, control) \times 2-time point ANOVA with repeated measures on condition and time point was utilized to examine differences in sit-and-reach performance in the college-aged nonathletes. Post hoc analyses of any significant interactions were explored using *t* tests with the Benjamini and Hochberg False Discovery Rate correction.⁴³ Wilcoxon signed rank tests were used to assess differences in perceived stiffness from pre- to post-BMS treatment for all groups and from pre- to postcontrol treatment in the college-aged nonathletes. The Benjamini and Hochberg False Discovery Rate correction was also applied to the *P* values from the multiple perceived stiffness comparisons.

RESULTS

Participant characteristics are shown in Table 1.

A significant ($P < .001$) main effect of time point (pre-, posttreatment) for differences in sit-and-reach performance was noted. Participants' post-BMS sit-

and-reach performance (30.1 ± 10.4 cm) was significantly better than pre-BMS (27.8 ± 10.6 cm; Figure 2, Table 2). A significant main effect of group was also noted ($P < .001$). Post hoc analysis revealed a significant ($P = .01$) stepwise increase in sit-and-reach performance from the older adults (21.7 ± 7.1 cm) to the college aged-nonathletes (29.3 ± 9.4 cm) to the college-aged athletes (39.2 ± 9.1 cm). No significant interaction effect was noted for pre- and posttreatment \times sex ($P = .3$) or pre- and posttreatment \times sex \times group ($P = .3$).

A significant ($P < .001$) condition (BMS, control) by time point (pre- and post-BMS) interaction for differences in sit-and-reach performance in the college-aged nonathletes who completed both the BMS and the control protocols was noted (Figure 2). The change in sit-and-reach performance from pre- to post-BMS treatment ($\Delta 2.9 \pm 2.3$ cm) was significantly greater than pre- to postcontrol ($\Delta 0.3 \pm 0.6$ cm).

Figure 3 illustrates the results of perceived low-back stiffness pre-and post-BMS treatment for the 3 study groups and pre-and postcontrol treatment in the college-aged nonathletes. College-aged nonathletes perceived themselves as significantly ($P < .001$) less stiff after BMS treatment, as did the college-aged athletes ($P = .05$) and older adults ($P < .001$). No change in perceived stiffness in the control condition ($P = .7$) was noted.

After receiving BMS, the college-aged athletes exhibited a 4.3% sit-and-reach performance improvement, the older adults improved by 8.2%, and the college-aged nonathletes' flexibility improved by 10.2%. During the control condition, sit-and-reach

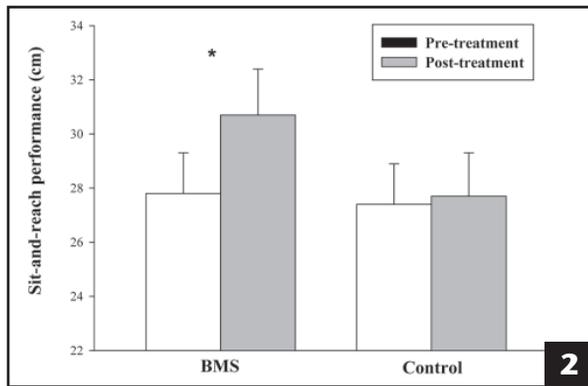


Figure 2. Sit-and-reach performance (cm) results for nonathletes pre- and postbiomechanical muscle stimulation (BMS) treatment and pre- and postcontrol (no treatment). * Paired samples *t* tests demonstrated that college-aged nonathletes exhibited greater improvement in sit-and-reach performance after receiving BMS treatment than after a control condition ($P < .001$). Error bars indicate standard error.

performance of the college-aged nonathletes' improved by only 1%. Perceived stiffness Likert scores for college-aged athletes improved by 1.8 units from pre- to post-BMS. The older adults' and college-aged nonathletes' stiffness improved by 1.7 and 2.0 units on the Likert scale, respectively. During the control condition, college-aged nonathletes' perceived stiffness improved by only 0.05 units on the Likert scale.

DISCUSSION

In the current study of segmental BMS, all participant groups (older adults, college-aged athletes, and college-aged nonathletes) exhibited significant improvement in low-back and hamstring flexibility and perceived back stiffness. No significant improvements in flexibility or perceived stiffness were noted in the college-aged nonathletes during a control condition.

Although it is possible for sit-and-reach performance to improve as a result of learning (ie, multiple tests may improve performance), this measure for the control condition increased by only 0.3 cm (1%), which was not a statistically significant improvement. In addition, only the highest score of 3 sit-and-reach assessments were used for the pretest and posttest in both the BMS treatment and control conditions. This was done to allow for the likelihood that performance could improve with subsequent assessments. Improvement in flexibility may occur as a result of either learning or reciprocal inhibition^{35,37}; however, the current results indicate that there were no significant improvements in flexibility in the absence of BMS treatment.

TABLE 2

Sit-and-Reach Performance Pre- and Postbiomechanical Muscle Stimulation Treatment in All Groups

GROUP	FLEXIBILITY ^a (MEAN ± SE) (CM)	
	PRETREATMENT	POSTTREATMENT
College-aged nonathletes	27.8 ± 1.5	30.7 ± 1.7
College-aged athletes	38.4 ± 3.1	40.0 ± 2.7
Older adults	20.9 ± 2.5	22.6 ± 2.4

Abbreviation: SE, standard error.

^a Flexibility significantly increased from pre- to posttreatment ($P < .001$).

In addition, stiffness scores were nearly identical pre- and postcontrol condition. This would suggest that the improvement in flexibility and perceived stiffness noted during the BMS treatment conditions were due to the BMS treatment and not the result of learning.

The results support previous studies that examined therapeutic interventions (eg, WBV, massage) that were similar to those used in the current study. In one such study, flexibility significantly improved in female field hockey players who received an acute treatment of WBV, whereas flexibility in the control group did not improve.⁴⁴ Similar to the current study, that study⁴⁴ utilized similar methods (sit-and-reach box) to assess changes in low-back and hamstring flexibility. Massage has also been shown to improve hamstring flexibility. Dynamic massage, including 20 seconds of manually shaking the muscle tissue, was shown to improve the degree of hip flexion angle in the intervention group, relative to controls.⁴⁵ That massage study⁴⁵ examined young men (aged 24.5 ± 5.3 years); however, the article does not indicate whether the participants had any special characteristics, such as a history of athletic participation.

Previous studies of older adults have shown that WBV is often successful at improving strength and mobility^{21,23,28,46}; however, little has been done to evaluate the effectiveness of vibration on flexibility in this population. To our knowledge, the current study is the first to examine the effects of segmental BMS on flexibility in the older adult. Despite having poorer flexibility, the older adults in the current study rated themselves as less stiff than the college age-athletes and nonathletes before the intervention. One possible explanation for this may be that younger adults expect themselves to be less stiff than they ac-

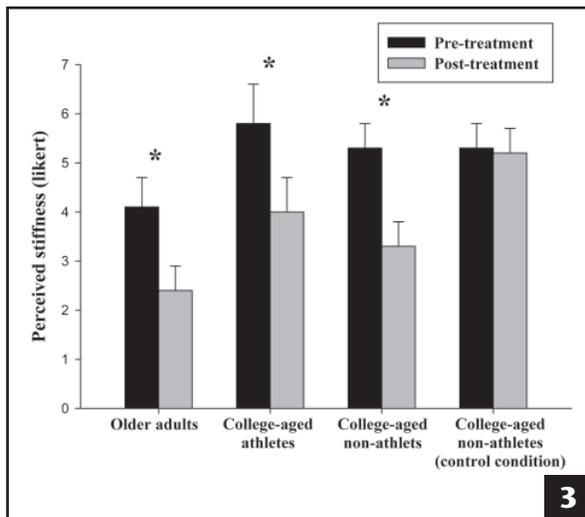


Figure 3. Perceived low-back stiffness pre- and postbiomechanical muscle stimulation (BMS) treatment for older adults, college-aged athletes, college-aged nonathletes, and the nonathlete control group (no treatment). * Wilcoxon signed rank tests demonstrated that each group of participants perceived themselves as less stiff ($P \leq .01$) after undergoing BMS treatment. No change in perceived stiffness in the control condition was noted ($P = .7$). Error bars indicate standard error.

tually are. It is also possible that years of life experience could result in older adults being less likely to complain about stiffness. The older adults, despite rating themselves as less stiff than the other groups pretreatment, reported a 41% decrease in perceived stiffness after treatment, which is more than any of the other groups. This indicated that BMS had the greatest effect on subjective measures of stiffness in the older adults. Nevertheless, all of the intervention groups rated themselves as less stiff after BMS treatment.

A comparison of other therapeutic intervention methods used to improve flexibility suggests that segmental BMS is at least as effective as, and in some cases is more effective than, other modalities. The use of proprioceptive neuromuscular facilitation has improved hamstring flexibility in young adults^{47,48} relative to static stretching. At the same time, static stretching has been demonstrated to be significantly more effective than active range of motion.⁴⁹ In terms of improvement, older adults showed an 8% improvement with 1 treatment in the current study. In a 2006 resistance training study,⁸ the older adult population improved dramatically as well, and an improvement of 3% to 28% in flexibility, depending on exercise intensity, over a 24-week period was shown.

The effect of segmental vibration has elicited various increases in flexibility, or range of motion, measures. One study examined various vibration loads in conjunction with stretching, using 44 Hz, resulting in a 2.1% increase in dynamic range of motion in young adult athletes.³⁷ The current study showed a 1% increase in college-aged athletes, utilizing 20 Hz, with no stretching. WBV has demonstrated an 8.2% improvement in sit-and-reach performance using 26 Hz and a single treatment.⁴⁴ Static stretching has revealed significant improvement in flexibility as well. An improvement of 32% from pretest to posttest has been shown; however, this was the result of a 6-week course of a stretching intervention.⁵⁰ The current research is unique in that it demonstrated as much as a 10% improvement in sit-and-reach scores, using low frequency and a single treatment.

The physiological mechanisms behind the increased flexibility and reduced stiffness with BMS treatment noted in the current study and previous studies^{51,52} utilizing different methodology are not completely understood but are likely due to neuromuscular, circulatory, and thermoregulatory mechanisms.³³ In the current study, it is not clear whether regional vibration improved flexibility or simply decreased discomfort (ie, reduced stiffness) from the extreme stretch, allowing participants more flexibility. It is likely that reciprocal inhibition is responsible for the improvement in sit-and-reach measurements. Vibration may affect the stretch-reflex loop through Ia inhibitory interneurons, causing relaxation of the antagonist muscle group.⁵³ Second, vibration may cause an increase in muscle temperature.^{35,54} This, in turn, reduces muscle stiffness and allows for greater stretch in the muscle. The tonic vibratory response is likely to have played a role in these changes, but it was not measured in the current study.

The current data demonstrate a treatment effect for young adult athletes and nonathletes, as well as for older adults; however, only the college-aged nonathletes completed the control condition. Future studies should include control conditions for both athletes and older adults. The current research was limited in that only healthy individuals were included in the study, and only low-back and hamstring flexibility were examined.

Other limitations existed in the current study. Participants self-reported low-back stiffness and were not experiencing any low-back disability at the time of

the study. The participants across all groups declared themselves as healthy and absent from injury. Another limitation in the study was that the control condition was managed within 1 of the existing groups. Finally, despite a breadth of literature on WBV therapy, there is little scientific data to support the exact physiological mechanisms for the increase in flexibility and the decrease in reported stiffness using BMS therapy. More research is needed in this area.

Future studies should examine the effects of BMS on injured individuals or on different areas of the body. In addition, this study assessed only acute effects of BMS. Subsequent studies should seek to determine whether any lasting changes may result from segmental BMS. It is unclear how long treatment effects last after 1 treatment or after repeated treatments. More research is also needed to determine the appropriate frequency of treatment, time of exposure to the vibration, and concomitant therapies. Finally, a comparison of WBV to segmental BMS could offer insight into the most effective vibration therapy delivery system for a variety of populations, including the elderly.

Low-back stiffness and lack of flexibility can be important predictors of back pain.^{53,55} Conversely, hamstring, hip, and low-back flexibility have been shown to be negatively correlated with low-back problems.⁵⁶ Improvement in flexibility in the general population has traditionally been attempted through stretching techniques. Although stretching can be valuable to some, research into other techniques to improve flexibility and reduce perceived stiffness is warranted. In the current study, BMS increased flexibility and decreased stiffness, and these improvements occurred with only a single treatment (in comparison with other interventions that required multiple weeks of treatment). Biomechanical muscle stimulation interventions are time efficient and appear to be effective in these particular participant groups. Therefore, although more research is needed, the current results indicate that BMS has potential as a treatment for improving low-back flexibility.

CONCLUSION

The current study demonstrated a significant improvement in low-back and hamstring flexibility, as well as perceived stiffness, after a brief segmental BMS treatment in 3 different groups of healthy, uninjured adults.

In addition, a control treatment did not alter flexibility or perceived stiffness in the college-aged nonathlete group.

IMPLICATIONS FOR CLINICAL PRACTICE

Segmental BMS is not widely used as a therapeutic modality. However, the noninvasive, relatively simple method of utilization and the evolving body of literature reflecting positive outcomes may encourage allied health care providers to investigate this modality as a viable treatment option for increasing hamstring and low-back flexibility and for decreasing perceived stiffness in younger and older populations when therapeutically indicated. ■

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