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Will Whole-Body Vibration Training Help Increase the Range of Motion of the Hamstrings?

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ABSTRACT

Will whole-body vibration training help increase the range of motion of the hamstrings? *J. Strength Cond. Res. 20(1):192–196. 2006.*—Muscle strain is one of the most common injuries, resulting in a decreased range of motion (ROM) in this group of muscles. Systematic stretching over a period of time is needed to increase the ROM. The purpose of this study was to determine if whole-body vibration (WBV) training would have a positive effect on flexibility training (contract-release method) and thereby on the ROM of the hamstring musculature. In this study, 19 undergraduate students in physical education (12 women and 7 men, age 21.5 ± 2.0 years) served as subjects and were randomly assigned to either a WBV group or a control group. Both groups stretched systematically 3 times per week for 4 weeks according to the contract-release method, which consists of a 5-second isometric contraction with each leg 3 times followed by 30 seconds of static stretching. Before each stretching exercise, the WBV group completed a WBV program consisting of standing in a squat position on the vibration platform with the knees bent 90° on the Nemes Bosco system vibration platform (30 seconds at 28 Hz, 10-mm amplitude, 6 times per training session). The results show that both groups had a significant increase in hamstring flexibility. However, the WBV group showed a significantly larger increase (30%) in ROM than did the control group (14%). These results indicate that WBV training may have an extra positive effect on flexibility of the hamstrings when combined with the contract-release stretching method.

Key Words: stretching, flexibility, proprioceptive neuromuscular facilitation

Introduction

An adequate range of motion (ROM) of different joints is very important for performance in sports and daily life. Factors such as age, gender, training background, active and passive muscle tension, ligaments, bone structure, and soft tissues influence the ROM of the joints (1). Some researchers propose that insufficient joint ROM caused by low muscle flexibility is a possible cause of muscle strain (11, 23, 26). It was also found that muscle strain resulted in a decreased ROM in the correspondent joints (11, 26).

Systematic stretching over a period of time is needed to increase the ROM. Different stretching methods such as static, ballistic, and proprioceptic neuromuscular facilitation (PNF) have been used to increase and maintain the ROM of joints (3, 21, 23). One of the most effectively used methods is the contract-release method, which has shown very good results in increased joint ROM and is more effective than static stretching (7, 8, 22). The mechanisms underlying the positive impact of PNF on joint ROM are the neurophysiological mechanisms involving the stretch reflex (18). These mechanisms may increase the "stretch tolerance," which can occur through increased tissue strength or analgesia (22).

Vibration training also influences the neurophysiological mechanisms because of the high accelerations (5). It elicits reflex muscle contractions (9), which results in neurogenetic adaptation (4, 20). Lundeberg et al. (13, 15) showed that induced vibrations affect pain sensations. Thus, the same mechanisms that are involved in PNF stretching are active in vibration training. This raises the question if vibration training would have an effect on the flexibility of the muscles and thereby on the joint ROM. Atha and Wheatley (2) found that 15 minutes of low-frequency vibration (44 Hz, amplitude 0.1 mm) conducted on the thighs and lower back increased the ROM of the hip flexion with the same amount as static stretching exercises. Issurin et al. (10) found that the joint ROM increased after the use of vibration in combination with static stretching. However, in their study, the vibration training was conducted while the subjects performed stretching exercises simultaneously. Neither of these studies used whole-body vibration (WBV) training on a platform.

Therefore, the purpose of this study was to determine if WBV training on a vibration platform would have a positive effect on flexibility training (contract-release method) and thereby on the ROM of the hamstring musculature. It was hypothesized that the ROM of the hamstrings increases more with WBV in combination with flexibility training than with flexibility training only.

Methods

Experimental Approach to the Problem

A repeated-measures design with a WBV group and a control group was used to determine the effectiveness of WBV training on flexibility training for the hamstring musculature during a 4-week training program.

Subjects

Nineteen undergraduate students (12 women and 7 men, age 21.5 ± 2.0 years) from the Department of Sports and Exercise Sciences, Sogn and Fjordane University College, Sogndal, Norway, participated in this study. Before participation, the subjects were fully informed about the protocol, and informed consent was obtained before all testing in accordance with the regulations of local ethical committee and with current Norwegian law and regulation.

Test Procedure

On the test days, the subjects warmed up by walking 2 minutes on a treadmill at a velocity of 4 $km \cdot h^{-1}$. Afterward, the subjects lay supine on a bench with the stretched leg raised and the knee fully extended. An assistant performed the measurements with a passive stretch of the hamstring musculature. The stretching was stopped when the leg began to tremble or when the subject said to stop. A goniometer was then used to measure the ROM as the angle (in degrees) between the femur and the pelvis with the greater trochanter as the rotation point. The opposite leg lay extended on the bench during the measurements. The measurements always began on the right leg and then alternated with the left leg after each attempt. The ROM of each leg was measured 3 times, and the average of these times was used in the further analysis. The test was always performed on the same day of the week (Friday) and at the same time of the day (1400–1800 hours) for each subject. The same 2 testers performed the passive stretches on the hamstrings and the measurements on all test days. They did not know which group the subjects belonged to when the subjects were tested. The test was performed before the training period started (pretest) and after each week of training (Figure 1) for a total of 5 times.

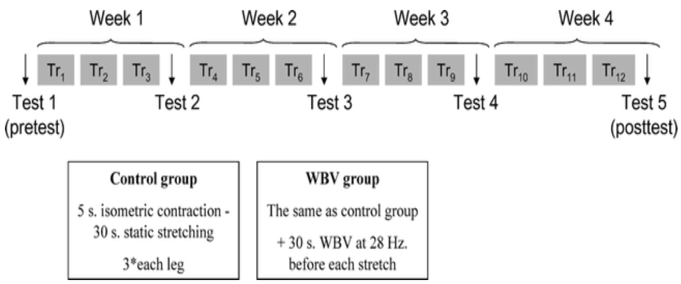

FIGURE 1. Experimental time line of the study, which includes the set-up of the training and test sessions. Tr_1 = training session 1; Tr_2 = training session 2, etc.

Training Procedure

After the pretest, the subjects were randomly assigned to either a WBV group (6 women and 4 men) or a control group (6 women and 3 men). No significant differences in ROM of the hamstrings were found between the men and women during the pretest ($p = 0.28$). The men were therefore equally randomly represented between the 2 groups.

Each subject was individually instructed at the first training session how to perform the flexibility training (both groups) and the vibration training (WBV group). Each subject was supervised during this session.

The training protocol consisted of a general 5-minute warm-up. Afterward, the subjects of both groups stretched their hamstring muscles systematically 3 times per leg according to the contract-release method protocol described by Bandy and Irion (3). Each subject assumed the standing position and was instructed to stretch the leg and place the heel on a table (the height of the table was the same for all subjects and remained constant throughout the study) so that the knee was fully extended and the foot was positioned in relaxed plantar flexion. Both legs were straightened without any rotation in the hip joint. An isometric contraction of the front leg was performed for 5 seconds by pushing the heel down on the table. Next, the hamstring muscles were stretched by bending forward at the hip while keeping the lumbar spine extended and maintaining the knee in full extension until the subject perceived tightness in the hamstrings. The subject held this position for 30 seconds before he or she could release the tension. Each leg was stretched alternately 3 times per training session. The subjects performed these sessions 3 times per week for 4 weeks.

Before each stretching exercise, the subjects from the WBV group were exposed to a vibration treatment on the Nemes Bosco system (OMP, Rieti, Italy) vibration platform for 30 seconds with a frequency of 28 Hz and amplitude of 10 mm (peak to peak). Each subject was asked to stand in a squat position on the vibration platform with the knees bent 90° (Figure 2).

FIGURE 2. Squat position on the vibration platform with the knees bent 90° during the whole-body vibration training.

This position was chosen because the vertical sinusoidal accelerations of the vibration platform had to be damped by the different muscles around the joints of the underextremity (17). It was thought that standing in this position induces involuntary muscular contractions (tonic vibration reflex) in the different muscles of the underextremity, including the hamstrings (4, 5, 17, 19). In the first sessions, each subject's position was checked and, if necessary, corrected by means of observational techniques.

Statistical Analyses

Statistical analyses were performed by using SPSS 11.5 for Windows. Differences in ROM of the hamstrings of the left and right legs were tested by a 1 × 5 repeated-measures analysis of variance (ANOVA).

To assess the effects of WBV and flexibility training on the average ROM of the hamstrings of both legs, a 2 × 5 repeated-measures ANOVA with the pretest results as a covariate (analysis of covariance [ANCOVA]) was used. A post hoc test (using Bonferroni probability adjustments) was used to locate significant differences. The level of significance was set for all statistical analyses at $p \leq 0.05$.

Results

One subject from the control group dropped out of the study because of an injury, which was not caused by the training protocol. Thus, 18 subjects completed the study (10 subjects from the WBV group and 8 from the control group).

No significant difference ($p = 0.37$, $r \geq 0.95$) in ROM of the hamstrings between the 2 legs was found; therefore, the average ROM of the both legs was used in further analysis. No significant differences in ROM of the hamstrings were found between the men and women during the pretest ($p = 0.28$). The men were therefore equally randomly represented between the 2 groups. A 2 × 5 repeated-measures ANCOVA showed a significant increase in ROM of the hamstrings in both groups as a result of training ($p = 0.024$, Figure 3).

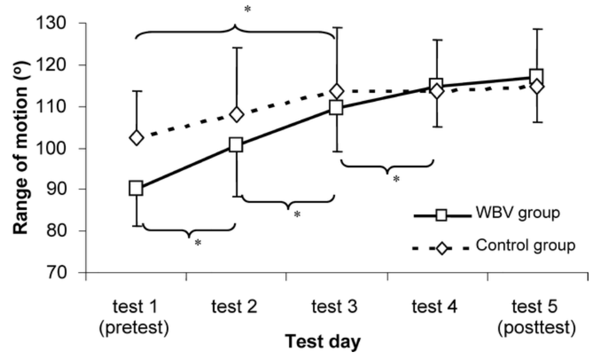

FIGURE 3. Average range of motion (ROM) of the hamstrings for the whole-body vibration group (square) and control group (diamond). * Significant differences in ROM between the correspondent test days ($p < 0.05$)

Also, a significant interaction between the groups was found ($p = 0.043$). No significant differences in the initial ROM of the hamstrings between the 2 groups were found ($p = 0.078$). In the WBV group, post hoc comparison (Bonferroni) showed that the significant increase occurred after 1 week of training and increased significantly after every training week except from week 3 to 4 ($p = 0.061$, Figure 3). However, in the control group, a significant increase was observed after 2 weeks and did not increase significantly more thereafter (Figure 3).

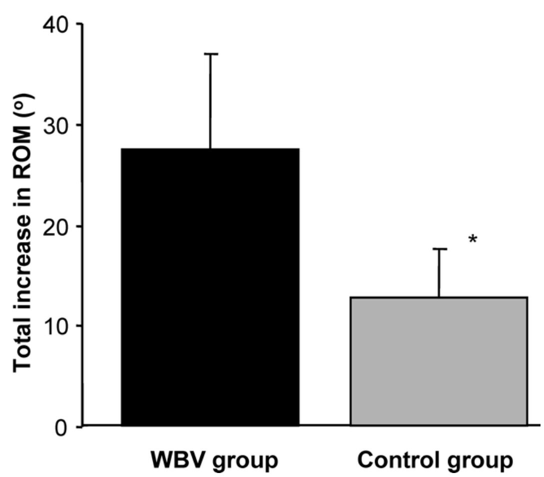

FIGURE 4. The average increase (in degrees) in the joint range of motion per group from the pretest to posttest. * Significant difference between the 2 groups ($p < 0.01$)

After calculating the average increase per group from the pre- to posttest, it was found that the joint ROM increased significantly more in the WBV group (26.8°) compared with the control group (12.4°) ($p = 0.002$, Figure 4).

This was also shown by the repeated-measures ANCOVA by the significant interaction between the groups.

No tendency was found for subjects who exhibited less ROM to have greater gains in ROM as a result of the training protocol. In this study, no significant correlation existed between the subjects' initial ROM test scores of the hamstrings and the total ROM test change scores ($p = 0.20$, $r = -0.32$). The correlations were contradictive when calculated per group (WBV group: $p = 0.41$, $r = -0.29$; control group: $p = 0.15$, $r = 0.55$) (Figure 5).

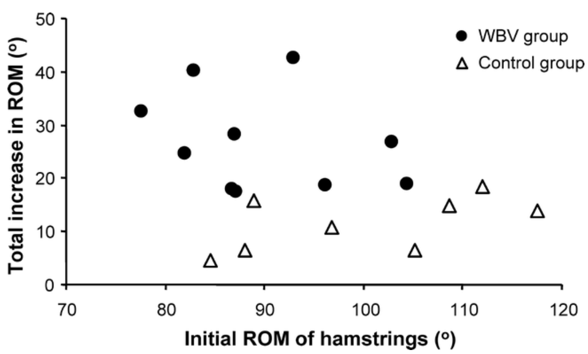

FIGURE 5. Correlation between the subjects' initial range of motion (ROM) test scores of the hamstrings and the total ROM test change scores ($p = 0.087$, $r = -0.43$). The correlations were contradictive when calculated per group (WBV group: $p = 0.41$, $r = -0.29$; control group: $p = 0.15$, $r = 0.55$).

Discussion

The use of the contract-release method during a 4-week period had a positive effect on the ROM of the hamstrings (Figure 3). However, combined with WBV training, the ROM increased significantly more (Figure 4). The control group had a higher initial ROM of the hamstrings than did the WBV group. This would result in a possible greater gain in ROM for the WBV group, for they would have a greater range for improvement. However, there were no significant differences between the 2 groups in initial ROM ($p = 0.078$). The suggestion that the WBV group could improve more was also not visible statistically, as shown by the low correlation of initial ROM of the hamstrings and the total gain of ROM after the training period for both groups ($p = 0.20$, $r = -0.32$). It was even observed that subjects of the control group with a high initial ROM gained more than those who had a lower initial ROM of the hamstrings ($p = 0.15$, $r = 0.55$). The opposite was observed in the WBV group ($p = 0.41$, $r = -0.29$). However, these correlations were not significant.

The increase in ROM of the hamstrings was in line with the earlier findings of Issurin et al. (10), who used superimposed vibrations at 44 Hz while the subjects performed their static stretching exercise. The authors also showed an increase in ROM twice as large in the vibration-training group (43.6%) as in the conventional flexibility-training group (19.3%), which is comparable with the findings in the present study (WBV group 30%, control group 14%). The high percentage of increase in the study by Issurin et al. (10) is a result of the flex-and-reach test (16), which measures the distance between the fingertips and a horizontal mark at foot level when the subjects flex their hip-trunk joint forward. This test includes the flexibility of several joints of the trunk, which also can increase by training. This may result in a larger increase in ROM than just testing the ROM of the hip joint, as performed in the current study. The increased flexibility measured by Issurin et al. (10) was in the range of 10.9 cm before training to 15.65 cm after vibration training, which results in the very large increases in percentage, as described earlier.

The superior result of WBV training on the ROM of the hamstrings compared with only flexibility training can be explained by 3 possible mechanisms. The first mechanism is the enhanced local blood flow immediately after vibration training (12, 19). Kerschan-Schindl et al. (12) found a local increased blood flow after 9 minutes of vibration training. This increase generates additional heat and thereby enhances muscle elasticity and facilitates a possible increased ROM during the stretching exercise.

Another mechanism may be neurophysiological. Vibration training elicits a tonic vibration reflex (9). The deformation of the soft tissues caused by vibration is capable of activating muscle spindle (25) and may lead to an enhancement of the stretch-reflex loop (5). The vibration-training frequency was at 28 Hz, which is about the same frequency as the natural frequency of the quadriceps (24). Thus, it is likely that the stretch reflex of the quadriceps muscles was stimulated in the current study during vibration training to damp the induced frequency (17). This was shown by an increased electromyogram (EMG) signal of the vastus lateralis of the quadriceps in a study by Cardinale and Lim (6). They showed that the signal was the highest at an induced vibration frequency of 30 Hz. Cardinale and Bosco (5) suggested that vibration training appears to inhibit activation of the antagonist muscles through Ia-inhibitory neurons. Thus, activating the quadriceps muscles would relax the hamstrings muscles and thereby have a positive influence on the stretching exercise.

Another possible mechanism stimulated in vibration training could be the proprioceptive feedback potentiation of inhibition of pain. This mechanism increases pain threshold; therefore, the joint position at which pain is sensed could increase (2). In the study by Issurin et al. (10), the subjects reported that sensations of pain were reduced 10–15 seconds after the beginning of static stretching during which vibration was applied. Lundeberg et al. (13–15) found that vibration training had analgesic effects on pain threshold. They showed that the pain threshold in subjects increased by 1.1–2.3 times the prestimulation threshold.

All these different mechanisms can help an individual perform stretching exercises with a larger ROM. This results in a more enhanced ROM of the hamstrings after 4 weeks of training compared with flexibility training only. However, in this study, the possible increased blood flow and responses of the neuromuscular system during training were not measured because of the lack of accessibility of measuring equipment. Future research should measure these mechanisms to gain more information about their use in vibration training and the role of this type of training on the ROM of joints.

Practical Applications

The results of this study indicate that WBV training has a positive effect on ROM of the hamstrings when combined with the contract-release stretching method. On the basis of the findings from this study, athletes who want to gain ROM in the hamstrings should use WBV training in combination with contract-release stretching. Contract-release stretching will already enhance ROM in the hamstrings, but when combined with WBV this ROM will improve even more. Strength and conditioning trainers should therefore prescribe this combined method if their athletes wish to gain a larger ROM in their hamstrings within a short period of time.

References

1. **Alter, M.J.** *Science of Flexibility*. Champaign, IL: Human Kinetics, 1996.
2. **Atha, J., and D.W. Wheatley.** Joint mobility changes due to low frequency vibration and stretching exercise. *Br. J. Sports Med.* 10:26–34.1976.
3. **Bandy, W., and J.M. Irion.** The effect of time on static stretch on the flexibility of the hamstrings muscles. *Phys. Ther.* 74:845–852. 1994.
4. **Bosco, C., R. Colli, M. Introini, M. Cardinale, M. Iacovelli, J. Tihanyi, S.P. Von Duvillard, and A. Viru.** Adaptive responses of human skeletal muscle to vibration exposure. *Clin. Physiol.* 19:183–187. 1999.
5. **Cardinale, M., and C. Bosco.** The use of vibration as an exercise intervention. *Exerc. Sport Sci. Rev.* 31:3–7. 2003.

6. **Cardinale, M., and J. Lim.** Electromyography activity of vastus lateralis muscle during whole body vibrations of different frequencies. *J. Strength Cond. Res.* 17:621–624. 2003.
7. **Etnyre, B.R., and E.J. Lee.** Chronic and acute flexibility of men and women using three different stretching techniques. *Res. Q.* 59:222–228. 1988.
8. **Funk, D.C., A.M. Swank, B.M. Mikla, T.A. Fagan, and B.K. Farr.** Impact of prior exercise on hamstrings flexibility: A comparison of proprioceptive neuromuscular facilitation and static stretching. *J. Strength Cond. Res.* 17:489–492. 2003.
9. **Hagbarth, K.E., and G. Eklund.** Motor effects of vibratory stimuli in man. In: *Proceedings of the 1st Nobel Symposium on Muscular Afferent and Motor Control.* R. Granit, ed. Stockholm: Almqvist and Wiksell, 1965. pp. 177–186.
10. **Issurin, V.B., D.G. Liebermann, and G. Tenenbaum.** Effect of vibratory stimulation training on maximal force and flexibility. *J. Sports Sci.* 12:561–566. 1994.
11. **Jonhagen, S., G. Nemeth, and E. Erikson.** Hamstrings injuries in sprinters: The role of concentric and eccentric hamstrings muscle strength and flexibility. *Am. J. Sports Med.* 22:262–266. 1994.
12. **Kerschan-Schindl, K., S. Grampp, and C. Henk.** Whole-body vibration exercise leads to alterations in muscle blood volume. *Clin. Physiol.* 21:377–382. 2001.
13. **Lundeberg, T., P. Abrahamsson, L. Bondesson, and E. Haker.** Vibratory stimulation compared to placebo in alleviation of pain. *Scand. J. Rehabil. Med.* 19:153–158. 1987.
14. **Lundeberg, T., P. Abrahamsson, L. Bondesson, and E. Haker.** Effect of vibratory stimulation on experimental and clinical pain. *Scand. J. Rehabil. Med.* 20:149–159. 1988.
15. **Lundeberg, T., R. Nordemar, and D. Ottoson.** Pain alleviation by vibratory stimulation. *Pain.* 20:25–44. 1984.
16. **Lycholat, T.** *The Complete Book of Stretching*. Aylesbury, UK: Crosswood Press, 1990.
17. **Nigg, B.M., and J.M. Wakeling.** Impact forces and muscle tuning: A new paradigm. *Exerc. Sport Sci. Rev.* 29:37–41. 2001.
18. **Prentice, W.E., and E.F. Kooima.** The use of proprioceptive neuromuscular facilitation techniques in the rehabilitation of sport-related injury. *Athl. Train.* 21:26–31. 1986.
19. **Rittweger, J., G. Beller, and D. Felsenberg.** Acute physiological effects of exhaustive whole-body vibration exercise in man. *Clin. Physiol.* 20:134–142. 2000.
20. **Rønnestad, B.** Comparing the performance-enhancing effects of squats on a vibration platform with conventional squats in recreationally resistance-trained men. *J. Strength Cond. Res.* 18:839–845. 2004.
21. **Ross, M.** Effect of lower-extremity position and stretching on hamstrings muscle flexibility. *J. Strength Cond. Res.* 13:124–129. 1999.
22. **Schrier, I., and K. Gossal.** Myths and truths of stretching: Individualized recommendations for healthy muscles. *Phys. Sports Med.* 28:57–63. 2000.
23. **Shellock, F.G., and W.E. Prentice.** Warming-up and stretching for improved physical performance and prevention of sport related injuries. *Sports Med.* 2:267–278. 1985.
24. **Wakeling, J., A. Liphardt, and B.N. Nigg.** Muscle activity reduces soft-tissue resonance at heel-strike during walking. *J. Biomech.* 36:1761–1769. 2003.
25. **Wakeling, J., B.N. Nigg, and A.I. Rozitis.** Muscle activity damps the soft tissue resonance that occurs in response to pulsed and continuous vibrations. *J. Appl. Physiol.* 93:1093–1103. 2002.
26. **Worrell, T.W., D.H. Perrin, B.M. Gansneder, and J.H. Gieck.** Comparison of isokinetic strength and flexibility measures between hamstrings injured and non-injured athletes. *J. Orthop. Sports Phys. Ther.* 13:118-125. 1991.

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