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The Effectiveness of Whole-Body-Vibration Training in Improving Hamstring Flexibility in Physically Active Adults

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Clinical Scenario: Hamstring tightness is common among physically active individuals. In addition to limiting range of motion and increasing the risk of muscle strain, hamstring tightness contributes to a variety of orthopedic conditions. Therefore, clinicians continue to identify effective methods to increase flexibility. Although hamstring tightness is typically treated with common stretching techniques such as static stretching and proprioceptive neuromuscular facilitation, it has been suggested that whole-body-vibration (WBV) training may improve hamstring flexibility. ***Clinical Question:*** Can WBV training, used in isolation or in combination with common stretching protocols or exercise, improve hamstring flexibility in physically active young adults? ***Summary of Key Findings:*** Of the included studies, 4 demonstrated statistically significant improvements in hamstring flexibility in the intervention group, and 1 study found minor improvements over time in the intervention group after treatment. ***Clinical Bottom Line:*** There is moderate evidence to support the use of WBV training to improve hamstring flexibility in physically active young adults. ***Strength of Recommendation:*** There is grade B evidence that WBV training improves hamstring flexibility in physically active adults. The Centre of Evidence Based Medicine recommends a grade of B for level 2 evidence with consistent findings.

Keywords: stretching, muscle, warm-up exercise

Clinical Scenario

Hamstring tightness is common among physically active individuals. In addition to limiting range of motion and increasing the risk of muscle strain,[1] hamstring tightness contributes to a variety of orthopedic conditions including patellofemoral pain,[2] plantar fasciitis,[3] and low back pain.[4] Therefore, clinicians are actively seeking effective methods to increase flexibility. Whole-body-vibration (WBV) training is a purportedly effective technique for exercise recovery[5] and enhancing lower-extremity muscle performance.[6] Although hamstring tightness is typically treated with common stretching techniques such as static stretching, dynamic stretching, and proprioceptive neuromuscular facilitation, it has been suggested that WBV training may improve hamstring flexibility.[7]

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Focused Clinical Question

Can WBV training, used in isolation or in combination with common stretching protocols or exercise, improve hamstring flexibility in physically active young adults?

Summary of Search, "Best Evidence" Appraised, and Key Findings

- The literature was searched for studies of level 2 evidence or higher that investigated the effect of WBV training on hamstring flexibility in physically active young adults.
- The literature search returned 24 possible studies related to the clinical question; 5 studies met the inclusion criteria and were included.[8–12]
- One high-quality randomized control trial (RCT)[12] and 4 low-quality RCTs were included.[8–11]
- Of the included studies, 4 demonstrated statistically significant improvements in hamstring flexibility in the intervention group,[9–12] and 1 study[8] observed minor improvements over time in the intervention group; however, the observed changes were not statistically significant.

Clinical Bottom Line

There is moderate evidence to support the use of WBV training, used in isolation or in combination with common stretching protocols or exercise, to improve hamstring flexibility in physically active young adults.

Strength of Recommendation: There is grade B evidence that WBV training, used in isolation or in combination with common stretching protocols or exercises, improves hamstring flexibility in physically active young adults. The Centre of Evidence Based Medicine recommends a grade of B for level 2 evidence with consistent findings.

Search Strategy

Terms Used to Guide Search Strategy

- **P**atient/Client group: *physically active young adults*
- **I**ntervention: *whole-body vibration*
- **C**omparison: *control*
- **O**utcome: *hamstring flexibility*

Sources of Evidence Searched

- CINAHL
- Cochrane Library
- PEDro Database
- PubMed
- SPORTDiscus
- Additional resources obtained via review of reference lists and hand search

Inclusion and Exclusion Criteria

Inclusion Criteria

- Limited to humans
- Limited to English language
- Limited to past 10 years (2004–2013)
- Level 2 evidence or higher investigating the effects of WBV training (eg, >2 wk) on hamstring flexibility in physically active young adults (18–30 y of age)

Exclusion Criteria

- Studies that included dancers
- Studies that did not include hamstring flexibility as an outcome
- Studies that examined the immediate/acute effects of WBV
- Studies that did not use a WBV platform

Results of Search

The 5 relevant studies[8–12] identified are categorized in Table 1 based on criteria identified in the levels of evidence as summarized by the Centre for Evidence Based Medicine in 2009.

Best Evidence

The 5 studies identified as the best evidence for inclusion in this critically appraised topic (CAT) are described in Table 2. They were selected because they were RCTs graded with a level of evidence of 2b or higher and examined the effects of WBV training on hamstring flexibility in physically active young adults.

Implications for Practice, Education, and Future Research

Although reviews have examined the use of WBV training on exercise recovery,[5] performance enhancement,[7,13,14] and injury prevention,[5] to date no one has critically appraised the literature on the effectiveness of the therapy for improving hamstring flexibility in physically active young adults. All 5 studies included in this appraisal found that WBV training alone or in conjunction with a stretching protocol or exercises increased hamstring flexibility in young physically active individuals with and without tight hamstrings.[8–12] Even though all of the studies are RCTs, only 1 study[12] met a minimum of 6 of the 10 PEDro-scale appraisal criteria to be considered high-quality evidence. Therefore, we concluded that a level B recommendation could be made for the use of WBV training to improve hamstring flexibility in physically active young adults because the included studies were level 2b evidence or higher with consistent findings.

Even though all of the RCTs included in this CAT used WBV platforms, their training protocols differed. Two of the studies[9,11] combined WBV training with a warm-up routine or platform exercises, and 2 studies[10,12] used WBV training with a static stretching routine,

Table 1 Summary of Study Designs of Articles Retrieved

Level of evidence	Study design	Number located	Reference
1b	Randomized controlled trial	1	van den Tillaar et al[12]
2b	Randomized controlled trial	4	Di Giminiani et al[8] Fagnani et al[9] Feland et al[10] Karatrantou et al[11]

Table 2 Characteristics of Included Studies

Characteristic	Di Giminiani et al[8]	Fagnani et al[9]	Feland et al[10]	Karatrantou et al[11]	van den Tillaar[12]
Study design	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial
Participants	40 physically active sport-science students. Students were excluded if they had a history of back pain, acute lower-extremity inflammation, bone tumors, recent fractures, severe delayed-onset muscle soreness of the hamstrings, or acute thrombosis. Subjects were randomly assigned to the acute or chronic group. In the chronic group subjects were randomly assigned to either receive WBV (4 men, 5 women; 21 ± 1.5 y) or serve as the control (4 men, 5 women; 22.2 ± 1.8 y). Two subjects withdrew due to loss of interest.	26 female competitive athletes. All subjects were participating in their respective sports more than 3 ×/wk. Exclusion criteria included chronic disease, pregnancy, prosthesis, or use of medications that could affect the musculoskeletal system. For each sport, half of the subjects were randomly assigned to the vibration group (24 ± 1.8 y) and the other half to the control (23.6 ± 1.9 y). Two subjects from the control group withdrew due to musculoskeletal injury.	34 recreationally active university students (22 male, 12 female; 23 ± 1.7 y) with "tight" hamstrings. *Tight* was defined as the inability to touch the tops of their feet from a standing position with the legs straight and 70° or less on a straight-leg raise test. All subjects were randomly assigned to 1 of 3 groups: control, static stretch (SS), or vibration + static stretch (V). Forty subjects were originally enrolled; 6 were removed for missed measurement sessions.	26 moderately active women randomly assigned to either a vibration (20.4 ± 0.4 y) group (VG) or a control (20.5 ± 0.4 y) group. All subjects were healthy and participating in low-level physical activities 2–3 ×/wk. None of the subjects had experience with WBV training.	19 undergraduate students (7 male, 12 female; 21.5 ± 2.0 y) from the Sogn and Fjordane University College in Sogndal, Norway. After the pretest, subjects were randomly assigned to either a WBV group (4 men, 6 women) or a control group (3 men, 6 women). One subject from the control group withdrew due to injury.
Intervention investigated	Subjects reported to the laboratory 3×/wk for 8 wk. All subjects were instructed to stand on the vibration platform (Nemes-Lsb, Bosco-System, Rieti, Italy) with their knees bent to 90° and to grasp the rail. During each session subjects in the vibration group received 10×/min WBV with 1 min rest between sets and a -min pause after the first 5 sets. The frequency of the vibrations was determined using EMG activity of the vastus lateralis. The average frequency was 37.9 Hz. The vibration platform was turned off for the control group.	All subjects in the vibration group were exposed to the vibration platform (Nemes LCB-040) 3×/wk for 8 wk using 2 different execution exercises. For exercise 1 (Ex #1), subjects stood upright on the platform with their knees bent to 90° and their hands on their hips. For Ex #2, subjects were positioned the same, but with 1 leg held in the air. The frequency of the vibrations was set at 35 Hz. Training load on the platform was as follows: Wk 1–2: Ex #1: 3 × 20 s (1-min rest between sets). Ex #2: 3 × 15 s (30-s rest between sets). Wk 3–4: Ex #1: 3 × 30 s (1-min rest between sets). Ex#2: 3 × 20 s (30-s rest between sets). Wk 5–6: Ex #1: 3 × 45 s (45-s rest between sets). Ex #2: 3 × 25 s (30-s rest between sets). Wk 7–8: Ex #1: 4 × 1 min (1-min rest between sets). Ex #2: 4 × 30 s (30-s rest between sets).	All subjects reported to the laboratory 5×/wk for 4 wk. The V group and SS group performed 5 (30-s) static stretches on a vibration platform (Galileo 2000, Orthometrix, White Plains, NY) with 30 s rest between stretches. Subjects were instructed to slightly bend the knees and flex at the hips, keeping the back as straight as possible, until the stretch in the hamstrings became slightly uncomfortable. They were also instructed to grab the support bar in front of them. Subjects in the V group performed the stretches with the platform running (26 Hz). The control group reported to the laboratory and waited 5 min for the other groups to complete the stretching protocol.	All subjects reported to the laboratory 1 wk before the study for a familiarization session and anthropometric measurements. The VG participated in a 16-session WBV-training program over the course of 3 weeks. During each session subjects received 2 × 5 min WBV with 2 min rest between sets. Subjects wore nonslippery socks and maintained an upright position on the vibration platform (Galileo Fitness, Novotec, Germany) with their knees flexed to 10°. The frequency was set at 25 Hz.	All subjects performed a stretching training protocol 3×/wk for 4 wk. The protocol consisted of a general 5-min warm-up followed by stretching the hamstrings on both legs 3× using a contract–release method. Before the stretching exercises, the WBV group stood in a squat position on a vibration platform (Nemes Bosco system, OMP, Rieti, Italy) with their knees bent to 90° for 30 s. Frequency was set at 28 Hz.

(continued)

Table 2 (continued)

Characteristic	Di Giminiani et al[8]	Fagnani et al[9]	Feland et al[10]	Karatrantou et al[11]	van den Tillaar[12]
Outcome measure	Hamstring flexibility was assessed using the stand-and-reach test on the vibration platform. The platform was turned off for the control group.	Hamstring flexibility was assessed using the sit-and-reach test.	Hamstring flexibility was assessed using the lying passive knee-extension test.	Hamstring flexibility was assessed using the sit-and-reach test (Flex-Tester box, Novel Products, Inc, Rockton, IL). Before testing, all subjects performed a standardized 10-min warm- up.	Hamstring flexibility was measured passively with the subject lying supine. Before testing, subjects warmed up by walking on a treadmill for 2 min.
Main findings	Chronic exposure to vibration training did not produce statistically significant changes in flexibility over time ($P > .05$).	Flexibility in the vibration group (baseline 19.6 ± 5.5 cm, end time 22.6 ± 4.6 cm) significantly improved over time ($P < .01$), while the control group (baseline 18.4 ± 4 cm, end time 19.5 ± 5 cm) did not ($P = .20$).	Both the SS (68.7°, $P = .002$) and V (71.7°, $P < .001$) groups demonstrated significantly greater flexibility than the control group (60.7°) after 4 wk of stretching. However, SS and V groups did not differ after 4 wk ($P = .02$).	Flexibility was greater in the VG (29.7 ± 0.9 cm) than the CG (25.7 ± 2.5 cm) at the completion of training ($P < .001$).	Flexibility significantly increased in both groups as a result of training ($P = .024$). However, WBV training (26.8°) significantly improved hamstring flexibility more than in the control group (12.4°) ($P = .002$).
Level of evidence	2b	2b	2b	2b	1b
Validity score	PEDro 4/10	PEDro 5/10	PEDro 4/10	PEDro 4/10	PEDro 6/10
Conclusion	Chronic exposure to WBV improved hamstring flexibility; however, the change was not significant.	Combined with 2 different exercises, WBV training enhanced hamstring flexibility in competitive female athletes.	Combined with static stretching, vibration training improved hamstring flexibility.	Combined with a standardized warm-up, WBV training improved hamstring flexibility; however, flexibility gains were not retained over time.	Combined with a contract–release stretching protocol, WBV training improved hamstring flexibility.

Abbreviations: RCT, randomized controlled trial; WBV, whole-body vibration.

whereas the other study[8] used WBV alone. It should be noted that although Di Giminiani et al[8] did not find significant differences over time, minor improvements in hamstring flexibility were observed in the vibration group. Furthermore, training protocols associated with the control groups also varied. For example, 1 study had the control group do the same flexibility exercises with the vibration platform turned off.[8] Another included the control group in the warm-up and stretching protocol.[12] The remaining studies[9–11] instructed the control group to either sit in the laboratory for a period of time or continue normal daily activities. In addition to the protocol differences, each study used WBV as the primary intervention; however, the vibration platforms were inconsistent. Three studies[8,9,12] used Nemes Bosco platforms and the other 2 studies[10,11] used Galileo platforms. Four studies[9–12] used preset vibration frequencies that ranged from 25 to 35 Hz. Di Giminiani et al[8] used EMG activity of the vastus lateralis to individually determine the preset frequency for each participant (20–55 Hz). To determine frequency, participants performed an isometric half-squat at 0, 20, 25, 30, 35, 40, 45, 50, and 55 Hz.[8] The frequency at which the highest neuromuscular response was recorded was used for the vibration intervention. Amplitudes ranged from 1 to 10 mm. To date, no research has compared the different platforms, yet each study was able to produce similar results with different parameters.

In addition to considering protocol and intervention differences, it is also important to consider the participants and quality of the evidence included in this CAT. Although participants were physically active and between the ages of 18 and 30, Feland et al[10] included participants with "tight" hamstrings. It is unclear whether the other studies included participants with tight hamstrings. Methodological quality of each study was determined using the PEDro scale.[15] The scale is designed to assess the internal validity and statistical reporting of RCTs. Criteria such as random allocation, blinding of subjects, and measures of variability are included on the 10-point scale. Studies that met ≥6/10 PEDro criteria were considered high-quality evidence. Four out of the 5 studies were classified as low-quality evidence.[8–11] Sources of bias included failure to conceal group allocation, lack of blinding, inadequate follow-up, and unspecified statistical analyses, as we could not determine if "intention to treat" was used. The van den Tillaar study[12] included blinding of both the therapists and the assessors, meeting 6 of the 10 appraisal criteria to be considered high-level evidence. Although PEDro scores ranged from 4 to 6 and participants may or may not have had flexibility deficits, all of the studies reported consistent results to confirm our level B recommendation.

Aside from hamstring flexibility, 3 studies found that WBV training improved other outcomes such as knee-flexor strength,[9] knee-flexor peak torque,[11] and power in the drop jump.[8] Therefore, it appears that WBV training may serve multiple purposes. However, it must be noted for each of these studies that the WBV intervention was combined with either platform exercises[9] or a warm-up routine[8,11] before testing these variables. Consequently, a direct causal relationship with an improvement in the outcomes measured cannot be attributed to the WBV intervention alone.

Based on the results of this CAT and our appraisal of each study, WBV is an effective clinical tool for improving hamstring flexibility when used on its own[8] or in combination with a stretching or exercise protocol.[9–12] Four of the 5 studies appraised that identified statistically significant differences between groups or over time suggest that WBV training be used in conjunction with a warm-up or stretching protocol. However, at this time it is unclear if a particular warm-up or stretching routine is better than another, as the articles used a variety of protocols in conjunction with the vibration training. Therefore, based on the majority of the evidence examined, we suggest implementing WBV training in conjunction with a self-warm-up or stretching protocol.

While we have presented 5 RCTs that validate WBV training as an effective technique to improve hamstring flexibility, future research is needed. The lack of consistency between research protocols suggests that future research emphasize uniform interventions, samples, and outcome measures. For example, the effects of WBV training should be explored in individuals with substantial flexibility losses, such as an injured or postsurgical population, to see if the intervention remains effective. In addition, research needs to be performed that uses a consistent vibration platform and outcome measures that are both valid and reliable to confirm the most effective way to use this treatment. Finally, high-quality evidence (level 1b) should be gathered to examine if WBV training has the ability to increase self-reported function or decrease the incidence of lower-extremity injuries related to hamstring tightness. This CAT should be reviewed in 2 years to determine whether there is additional best evidence that may change the clinical bottom line for this clinical question.

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