

Original Article

Cross transfer acute effects of foam rolling with vibration on ankle dorsiflexion range of motion

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Introduction: Foam roller is a device used as a massage intervention for rehabilitation and fitness performance. **Objective:** To examine the effects on the ankle dorsiflexion mobility of the foam roller as well as the combination of foam roller and vibration applied to the ankle plantarflexors muscles, and to observe the possible cross-effect. **Methods:** Thirty-eight undergraduate students participated in the study (19 males and 19 females). This study investigated. Three conditions (3 sets of 20 s) were performed in a randomized order (independent variables): 1) foam roller (Roller), 2) foam roller and vibration (Roller+VIB), and 3) no foam roller or vibration (Control). to determine whether of foam roller with or without vibration would benefit ankle dorsiflexion mobility. Ankle dorsiflexion ROM and plantar flexor were measured in both legs before and immediately after the treatment. **Results:** A cross-effect was found in the non-stimulated leg. There was a significant effect on ankle mobility of Roller and Roller+VIB conditions (6% and 7%, $p < 0.001$). **Conclusion:** Foam roller massage and vibration stimulus' foam roller massage increase ankle mobility producing a cross-effect.

Keywords: Massage, Self-Miofascial Release Mobility, Strength**Introduction**

Foam rolling is a popular technique used as a self-massage intervention. The principal use of this type of self-massage release is for rehabilitation and fitness performance to enhance myofascial mobility. Previous evidence has reported foam rolling can increase joint range of motion (ROM)¹ and improve the recovery process². Regular, intense or unaccustomed exercise can evoke a possible pain effect on muscle, where foam rolling has been shown to reduce delayed onset muscle soreness (DOMS)³ and decrease perceived fatigue⁴. Currently, there are two commercial foam rollers that have been used in previous research, such as the standard model (15.24 cm x 91.44 cm)²⁻⁸ and half size model (15.24 cm x 45.72 cm)⁹ where body weight of the individual is used to apply pressure to soft tissues during the rolling motion¹⁰.

Foam rolling is an effective intervention for enhancing joint range of movement in pre- and post-exercise muscle performance¹⁰ but currently there is no defined program of foam roller massage due to the heterogeneity of methods reported in previous studies¹⁰. To increase ROM various methods of stretching are often employed, such as, static, ballistic, and dynamic stretching as along with proprioceptive neuromuscular facilitation¹¹. Static stretching is commonly utilized, however when it is implemented as part of warm up, muscular power and performance decreases¹². If the myofascia is injured, inactive, or inflamed it can restrict ROM and decrease strength and endurance¹. Currently there is a plethora of practitioner-partnered techniques to treat fascia such as, osteopathic soft-tissue manipulations, structural integration, massage, muscle energy techniques, and Graston¹³. However, an alternative technique that is independent of a practitioner, is self-induced myofascial release, which can be facilitated with a foam roller or roller massager¹¹. In several studies foam rolling has demonstrated an increase in ROM measure^{8,13-14}.

Another training method that has been popular over the last decade is vibration therapy. The vibration stimulus can be applied directly to the muscle or tendon or indirectly to the whole body where the stimuli enters via the feet while standing on a vibration platform¹⁵. The use of direct vibration

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therapy as a recovery modality to reducing muscle soreness and fatigue is gaining a lot of interest. For instance, applying direct vibration therapy to elbow flexors following strenuous eccentric exercise has been shown to attenuate muscle soreness and improve ROM¹⁶. However, little is known about the efficacy of combining foam roller with vibration to enhance ROM improvements. In most instances unilateral foam rolling occurs, however there is paucity of information whether unilateral exposure to foam rolling can improve performance of the other leg. Previous studies have observed strength changes in the non-trained limb¹⁷ of knee extensors¹⁸⁻²⁰ and elbow flexors^{21,22}. Likewise, Shima et al.²³ found that after 6 weeks training of single leg calf raises and plantar flexion a cross-effect was apparent in ankle plantarflexors of the contralateral leg.

Currently, there is a lack of knowledge about the use of concurrent vibration and roller and its efficacy to elicit a cross-effect on the contralateral leg to improve ROM. Therefore, the main purpose of this study was to examine the effects on the ankle dorsiflexion mobility of the foam roller as well as the combination of foam roller and vibration applied to the ankle plantarflexors muscles, and to observe the possible cross-effect. We hypothesized that vibration combined with foam roller would induce an increase in ankle dorsiflexion mobility for the leg that receives the stimulus and the contralateral limb.

Materials and methods

Experimental design

This study investigated whether 3 sets of 20 s of foam roller with or without vibration would benefit ankle dorsiflexion mobility. Ankle dorsiflexion ROM and plantar flexor were measured in both legs before and immediately after the treatment. Three conditions were performed in a randomized order (independent variables): 1) foam roller (Roller), 2) foam roller and vibration (Roller+VIB), and 3) no foam roller or vibration (Control). All treatment conditions were applied to the dominant leg and were separated by at least 48 hours and were conducted at the same time of day to take into account for daily biorhythms. The preference for kicking a ball was the criteria to determine participant's dominant leg.

Participants

Thirty-eight undergraduate students participated in the study, 19 females (19.5±7.2 y, 167.8±0.1 cm, 59.2±2.2 kg) and 19 males (21.8±2.7 y, 178.9±0.1 cm, 73.7±9.1 kg). One female and 5 males indicated left leg dominance. Each participant performed all 3 conditions to minimize inter-individual variance in muscle response. All participants were recreationally active but none were involved in a systematic exercise-training program at the time of data collection or for at least 2 months prior to the study. Prior to data collection participants were informed of the requirements associated with participation and provided written informed consent.



Figure 1. Ankle ROM test.

Exclusion criteria were diabetes, epilepsy, gallstones, kidney stones, cardiovascular diseases, joint implants, recent thrombosis, as well as musculoskeletal problems. Participants were encouraged to maintain their dietary, sleeping, and drinking habits during the study. Two to three days before the testing sessions, participants attended one familiarization session. The study was conducted according to the Declaration of Helsinki and was approved by the University Review Board for use of Human Subjects.

Foam rolling and vibration

A commercial foam roller (Vyper®, Hyperice, Irvine, USA) with three different vibration frequencies that produced uniform oscillations was used in the current study. The roller was set at the medium setting with the following parameters; a frequency of 49 Hz with an amplitude of 1.95 mm (distance from peak-to-peak). Using a three-axial accelerometer (Vibration Datalogger DT-178A, Ruby Electronics, Saratoga, USA) with 60 kg on foam roller it generated an acceleration of 92.6 m·s⁻². This was obtained via the vector sum of the accelerations and data analysis was performed using specific software (Vibration Datalogger DT-178A, Ruby Electronics, Saratoga, USA). During all the conditions, participants did not wear any clothing on the calf or socks.

Ankle ROM test

The ROM of ankle dorsiflexion was assessed using Leg Motion system (Check your MOtion®, Albacete, Spain), which is a portable tool used to measure ankle dorsiflexion during a weight-bearing lunge²⁴. Participants were tested before (Pre) and after (Post) for each condition (Figure 1). All assessments were conducted by the same researcher according to the reliability protocol established by Ortega and colleagues²⁵. The leg motion ankle dorsiflexion test was preceded by two warm-up attempts with the third attempt recorded. Each participant started with their hands on their



Figure 2. Foam rolling technique.

hips, where the assigned foot was located on the middle of the longitudinal line just behind the transversal line on the platform. The contralateral foot was positioned to the side of the platform. While maintaining this position, participants were instructed to perform a lunge where the knee was flexed with the goal of making contact between the anterior knee and the perpendicular metal stick. When participants were able to maintain heel and knee contact, the metal stick was progressed away from knee. The distance achieved was recorded in centimeters. Three trials were performed for each ankle (dominant and non-dominant) with 10 seconds of passive recovery between trials. The third value from each ankle was selected for subsequent analysis of weight-bearing dorsiflexion ROM (DF ROM)²⁶.

Maximal voluntary isometric contraction

A custom-made ankle strength device was used to measure maximal voluntary isometric contraction (MVIC) plantarflexion (PF) and dorsiflexion (DF) force. Participants were seated on a chair, with their trunk, thighs, lower thighs, and foot fastened to the chair and the force meter device. The DF and PF were calculated as the tensile and compressive force of a strain gauge (Winlaborat V4.20, Buenos Aires, Argentina).

Participants then performed three trials at maximal effort of 4 seconds with a 1-min rest period between trials to minimize muscle fatigue. The average of three measures was calculated. DF ROM, PF, and DF were re-measured on a different day to determine the test-retest repeatability of such measurements, by calculating intraclass correlation coefficient (ICC).

Treatment protocol

Participants began all experimental sessions with a warm-up consisting of 10 bilateral heel rises at a duration of one second to rise the heels and 1 second to for the heels to make contact with the ground. Each participant performed three separate conditions in a randomized order in barefoot. 1) Roller (roller only), 2) Roller+Vibration (roller and vibration

at 32 Hz), 3) Control (sitting on a chair). The Roller consisted of 3 sets of 20 seconds in duration with a 10-second rest between sets²⁷. Thus, the volume of work performed in the Sham condition was equalized. Foam rolling was performed in a seated position with the legs extended and the foot relaxed as shown in Figure 2. Participants were instructed to use their arms to propel their body back and forward, from popliteal fossa to Achilles tendon, in a smooth and continuous motion of 3 seconds forward and 1 second backward and then vice versa from Achilles tendon to popliteal fossa. The first set was performed on the lateral side of the triceps sural, the second set on the center and the third set on the medial side of the triceps sural. They were also instructed to exert as much pressure on the dominant leg, whilst the contralateral leg was placed on a body-mass scale to avoid exerting additional pressure. The measures of DF ROM, PF, and DF were made before and immediately (less than 10s between condition and measure) after the treatment in both legs in a randomized order.

Statistical analysis

Data were analyzed using PASW/SPSS Statistics 20 (SPSS Inc, Chicago, IL) and significance level was set at $P \leq 0.05$. All the measures were normally distributed, as determined by the Kolmogorov-Smirnov test. Sphericity was tested by the Greenhouse-Geisser method.

Dependent variables (DF ROM, PF, and DF) were evaluated with a two-way repeated measures analysis of variance (ANOVA) of condition x time. Where significant F values were achieved, pairwise comparisons were performed using the Bonferroni post hoc procedure. Effect size statistic, η^2 , was analyzed to determine the magnitude of the effect independent of sample size. Values are presented as mean \pm standard deviation (SD).

Results

The ICCs of DF ROM, PF, and DF were 0.98, 0.87 and 0.89, respectively.

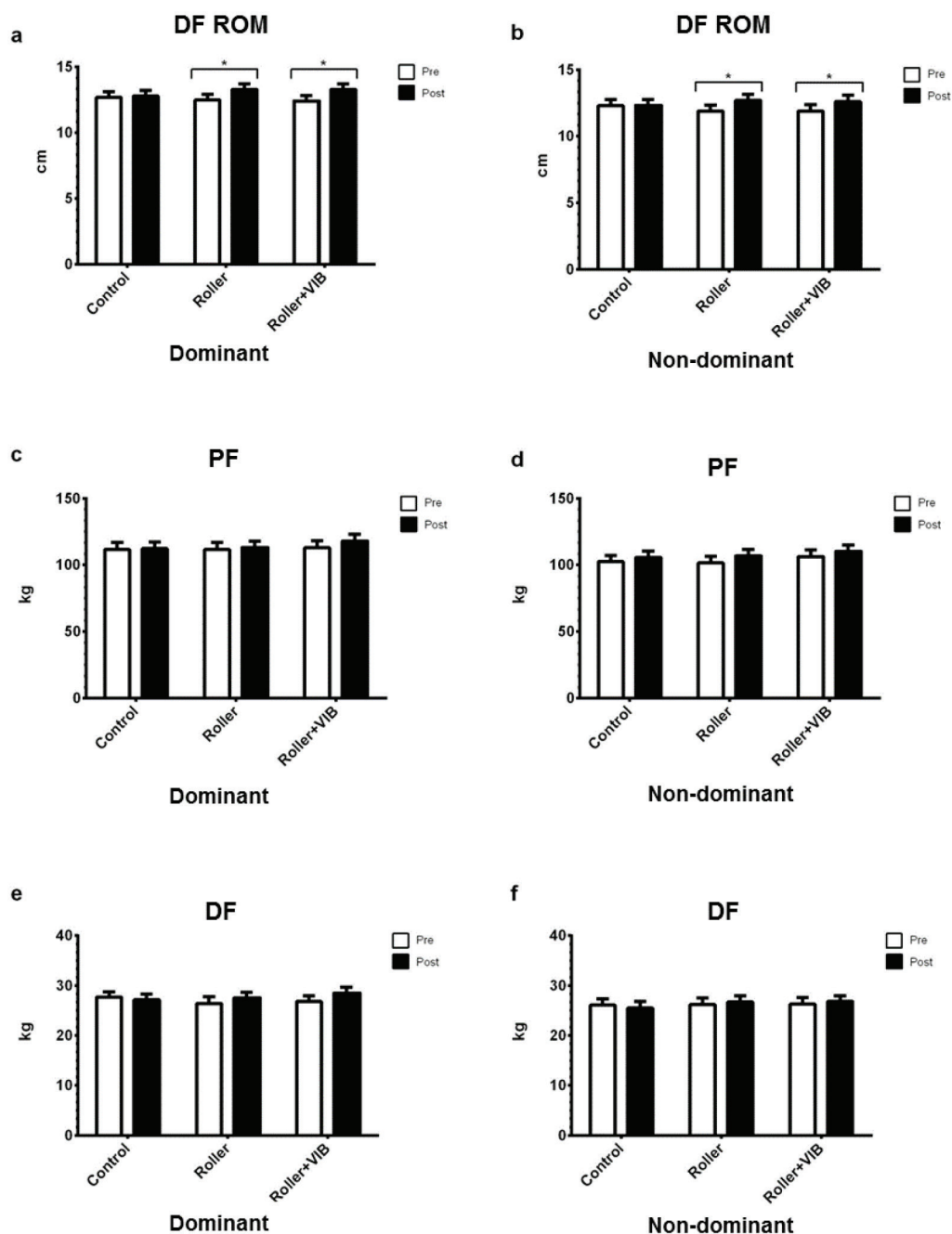


Figure 3. a & b - DF ROM of dominant and non-dominant limb; c & d - PF of dominant and non-dominant limb of control, roller and roller + vib conditions. DF ROM = dorsiflexion range of motion; PF = plantarflexion force; DF = dorsiflexion force.

Ankle ROM

Ankle dorsiflexion ROM was higher in Roller and Roller+VIB compared to Control for both legs ($p < 0.001$; $\eta^2 = 0.394$). After Roller condition, dominant leg and non-dominant leg reported a 6% of improvement of ankle dorsiflexion ROM, while for Roller+VIB condition dominant leg increase 7% and non-dominant leg 5% (Figure 3a and 3b). A significant time

effect ($p < 0.001$; $\eta^2 = 0.762$) was observed in all conditions, and a leg effect was found ($p < 0.05$; $\eta^2 = 0.099$) (Figure 3a and 3b).

Maximal voluntary isometric contraction

There was no significant difference in the PF (Figure 3c and 3d) or DF (Figure 3e and 3f) between conditions ($p > 0.05$).

Discussion

The main finding of the present study was foam roller or foam roller and vibration stimulus of the dominant calf muscle elicited an increase in ankle dorsiflexion ROM in the treated and contralateral limb. In contrast, MVIC was not affected by foam roller. To the best of our knowledge, this is the first study to assess the effects of foam rolling with foam roller combined with vibration, as well as the first study to observe the effects of this treatment on the contralateral limb. Moreover, previous studies have reported that foam rolling can have a positive influence on ankle dorsiflexion ROM and it is capable of eliciting cross-over effect on the contralateral limb^{9,27}.

Pellegrini et al.²⁸ investigated the acute effect of whole body vibration (WBV, 26 Hz, 4-4.5 mm amplitude) on the voluntary activation of the ankle plantar flexors in healthy young adults and reported that after 5 sets of 1 minute of stretching of the plantar flexors with WBV that plantar flexor force increased. In contrast, the present study found no significant increase in plantarflexor MVIC. Our current results used a higher frequency vibration stimulus (49 Hz) compared to a lower frequency in previous work (26 Hz). Our work also used a different vibration device, a vibration roller versus a vibration platform. However, the methodology may explain the dissonance, in the current study we analyzed isometric muscle action but Pellegrini et al.²⁸ study used an isokinetic exercise protocol. Furthermore, Harwood et al.²⁹ revealed that isometric plantar flexor performance decreased immediately following five 60-seconds bouts of WBV (45 Hz, 2 mm amplitude) and as a result of consecutive acute bouts of vibration the authors suggested the Ia pathway was compromised.

In support of the current findings a recent study analyzed the effects of foam rolling on muscle recovery after exercise-induced muscle damage (EIMD), and concluded that foam rolling had no effect on plantar flexor performance, morphology, and oxygenation recovery after EIMD, except for muscle pain pressure threshold³⁰. Furthermore, the present findings indicate the Roller increased ankle dorsiflexion ROM of dominant and non-dominant leg by 6%, while Roller+VIB increased ROM in the dominant leg (7%) and non-dominant (5%). This is similar to 4-10% ROM improvement reported by previous studies of the hamstrings¹ and ankle dorsiflexion³¹.

However, the additive effect of vibration with foam rolling did not significantly improve ROM compared to foam rolling alone. Additionally, it did not enhance plantarflexion and dorsiflexion isometric strength. Although the foam roller was acting directly on the triceps sural, it is possible that the current rolling duration of 3 seconds forward and 1 sec backward for 20 seconds may have not been substantial for the vibration stimulus to elicit the appropriate responses to enhance muscle performance. Therefore, a higher vibration frequency and amplitude, along with a slower rolling duration may be required to ensure that the additive component of vibration can be realized. Moreover, it is plausible that

the force applied during foam rolling may have nullified the additive effect of vibration. Further research is required to determine if an optimal force is required on the muscle group when vibration is combined with foam rolling.

Despite the ROM increase being similar in both conditions (Roller and Roller+VIB) it is difficult to ascertain the mechanism(s) for its improvement, as there may be various aspects that are involved. Without direct evidence it is difficult to substantiate, however one may speculate that changes occurred in the viscoelastic elements of the musculotendinous unit^{32,33} and that stretching tolerance of ROM improved³⁴.

The concept of cross-over effect has been well documented in unilateral resistance training where neural adaptations are the likely mechanism³⁵ to eliciting changes on contralateral strength¹⁷. The findings of the present study indicate that ROM was enhanced in the affected and the contralateral limb. This is supported by Jay et al.³⁶ who reported that following exercise induced DOMS, acute muscle soreness was reduced and pain threshold was increased from 10 minutes from foam rolling the hamstrings of the ipsilateral limb; additionally, there was a tendency of reduced muscle soreness in the contralateral limb. The authors postulate that central pathways may be a potential source to eliciting the cross-over transfer. In contrast, the current results showed that combining vibration with foam rolling had little effect on ROM, therefore it is likely that the participant's force applied to the roller of the ipsilateral limb may have caused a global response of stimulating the mechanoreceptors, which supports the idea of a cross-over effect of the contralateral limb²⁷.

In conclusion, the present study documents for the first time that foam rolling combined with vibration increases dorsiflexion ROM and a cross-over transfer effect was observed in the contralateral limb. However, the addition of the vibration stimulus with foam rolling did not further increase ROM compared to foam rolling alone. Thus, there seems little benefit of including vibration with foam rolling to increase ROM, however further research is required to determine its prophylactic or therapeutic recovery ability to deter muscle fatigue and accelerate muscle performance.

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