

Original Article

Percussion Massage Therapy Reduced EMG Activity During Standing Heel Raise

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Abstract

Objectives: This study examined the acute impact of percussion massage therapy (PMT) on calf muscle activation during heel raises in individuals with and without chronic ankle instability (CAI). **Methods:** Thirty-nine university students, 20 with CAI and 19 controls, were randomized to 30 seconds of PMT or no intervention (NOPMT). Surface EMG measured medial gastrocnemius activity during heel raise before and after. **Results:** Pre-intervention, CAI limbs displayed significantly lower peak muscle activation than limbs without CAI (26%, $p = 0.012$). Post-intervention, both PMT groups showed significant reductions in peak EMG (CAI: 10%, controls: 12%, $p < 0.05$), while NOPMT groups remained unchanged. **Conclusion:** These results indicate CAI is associated with reduced calf muscle activation, and PMT further decreases it. However, PMT's activation-reducing effect may be counterproductive when increased muscle activation is desired, necessitating further research on PMT's interaction with activation exercises. Further research is needed to explore the long-term effects and optimal timing of PMT in rehabilitation and athletic settings.

Keywords: Ankle Injury, Electromyography, Lower Limb Injury, Muscle Activation, Plantar Flexion

Introduction

Ankle injuries are common in most sports and have a high re-injury rate of 12-47%¹. Recurrent ankle sprains can lead to a chronic unstable ankle, characterized by laxity, functional and biomechanical instability, and persistent discomfort that disables motor activity². Acute ankle sprain to chronic ankle instability (CAI) conversion happens shortly after the first acute ankle sprain, since the symptoms, such as pain, swelling and recurrent injury are often present even after rehabilitation³. Research indicates that individuals

with CAI have decreased electromyographical (EMG) activity in muscles around the foot and ankle^{4,5,6}. This results in compensatory effects higher up the lower extremity, evidenced by increased hip muscle activation^{7,8} and altered activation patterns^{9,10,11}. Individuals with CAI also have delayed neuromuscular activation of the peroneus longus nerve and altered neural excitability in the soleus muscle¹². Additionally, they exhibit 30% lower muscle contraction during running compared to individuals without CAI³. These deficits in neuromuscular responses and muscle strength have also been found in complex tasks, such as postural stability or gait initiation, in patients with CAI¹³. The variety of clinical impairments highlights the need for innovative therapeutic approaches to elevate neuromuscular function in individuals with CAI.

Percussion massage therapy (PMT), a newly emerging modality, is gaining attention for its potential muscle performance optimization and in mitigating neuromuscular deficits. This method is based on deep tissue muscle massage with a battery-powered device that strikes the

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Table 1. Descriptive Research Group Characteristics.

	Age (years)	Body height (cm)	Body weight (kg)
	(mean \pm SD)	(mean \pm SD)	(mean \pm SD)
Total	23.7 \pm 1.3	176.2 \pm 10.1	71.1 \pm 12.3
CAI	23.4 \pm 1.4	176.1 \pm 10.5	70.9 \pm 10.8
CON	23.9 \pm 1.2	176.3 \pm 10.2	71.3 \pm 14.1

Abbreviation: CAI (chronic ankle instability); CON (controls); SD (standard deviation).

tissue with a rubber head. PMT devices can function at varying frequencies reaching up to 53 Hz or 60 times per second, depending on the model and construction^{14,15}. While the goal of the intervention is to irritate the nervous component, and thus “activate the muscles”, research has found mixed results. While it has been shown that pre-exercise PMT may not effectively influence physiological processes leading to improved performance¹⁴, others have observed changes after PMT use such as increased range of motion in ankle dorsiflexion¹⁶. However, there remains a gap in the literature as the effect of PMT on muscle activation during a dynamic performance task has not been previously studied. The standing heel raise is a fundamental task in dynamic movement initiation, which is often used to assess foot and ankle muscle function^{17,18,19}. Its demands on the calf musculature and assessment of plantarflexor strength make it an ideal test for assessing neuromuscular responses, particularly in those with limitations at the foot and ankle, such as in CAI^{18,20,21}.

Thus, the aim of this research was to examine the effect of PMT on calf muscle EMG activation patterns during a standing heel raise task in individuals with CAI and controls without a history of CAI. The hypotheses were that individuals with CAI would exhibit lower calf muscle activation during heel raise than controls. Furthermore, PMT would increase the peak muscle activity in both groups immediately following the intervention during a heel raise.

Materials and Methods

Experimental Approach to the Problem

This study used a randomized controlled trial to assess the effect of PMT in individuals with and without a history of CAI. In order to accurately assess the intervention's effect on both groups, participants were first divided into a previous history with or without CAI and then randomized using computer generated sequences into PMT or no-PMT (NOPMT) intervention. Data collection of muscle activity during the standardized standing heel raise task was performed by surface EMG attached to the medial gastrocnemius muscle bilaterally. A total of 4 standing heel raise trials, with 15 second rest in-between, were performed

before and after the intervention, for a comparison of the effect of the intervention on the calf muscle activation during the test. Between pre- and post-test, there was a one and half minute period during which each participant was in a prone position on a medical examination bed. The massage gun used was the Theragun PRO plus, set at 2100 beats per minute (35 Hz), applying approximately 1 bar (~14.5 psi) of pressure, as per manufacturer instructions. The experimental PMT groups received a 30-second triceps surae massage on each limb, while the control group maintained the same prone position without massage. The massage gun was set the same for each participant (detailed below), while the movement was performed according to the manufacturer's instructions.

Participants

A power analysis predicting a medium effect size ($F2 = 0.15$, with a significance level of alpha 0.05 and a test power of $1-\beta = 0.8$) determined that a number of approximately 40 participants were required. Injury history was gathered by verbal questioning of the participants. The criteria for the chronicity of CAI group were at least two episodes of ankle sprains, ankle subluxations, or ankle distortions in the last two years as reported by a physician. All CAI subjects reported persistent symptoms such as instability or symptoms of persistent instability (experience of “giving way”) lasting for more than six months following their most recent injury, however, no additional questionnaire or clinical testing about severity of the ankle sprain grades was performed. Total of 20 participants with CAI and 19 controls (CON) without CAI diagnosis participated in the current study. In both groups, participants were randomly allocated, with a balanced ratio between male and female participants, into two subgroups based on whether they received the PMT intervention or no intervention: CAI-PMT ($n=10$), CAI-NOPMT ($n=10$), CON-PMT ($n=9$), CON-NOPMT ($n=10$). Basic group characteristics are shown in Table 1.

Apart from defined CAI, the following exclusion criteria were used: history of musculoskeletal injury, orthopaedic surgeries, paraplegia, currently pregnant, a history of fever or acute inflammatory diseases within 7 days before the measurement, current or healed rupture of



Figure 1. Side view of starting/final during standing heel raise task.



Figure 2. Side view of transition position from concentric to eccentric phase during standing heel raise task.

m. gastrocnemius, m. soleus, tendo calcaneus, current purulent, fungal diseases, burns, scalds, varices, or any neurological diseases.

Procedures

Data Collection

Data collection of muscle activity during the standing heel raise task was performed by surface EMG (Trigno, Delsys Inc., Natick, USA) attached to the medial gastrocnemius muscle bilaterally. The area of sensor application was cleaned, shaved, and again cleaned with medical alcohol wipes (Medipal, Alcohol Wipes). The precise location of the sensor placement on the muscle belly was marked by a removable marker dot, which allowed sensor reattachment in the same place after the PMT procedure. The EMG sensor was directly attached to the measurement place by double sided adhesive stickers from the manufacturer (Delsys Inc., Natick, USA). EMG activity was recorded simultaneously in all tests with sample rate at 2048 Hz. Bandwidth of EMG signal was high-passed (4th-order Butterworth) at 20 ± 5

Hz and low-passed (4th-order Butterworth) at 450 ± 5 Hz for further analysis²². EMG data underwent full-wave rectification and smoothing²³. For EMG normalization, peak root mean squared (RMS) muscle activity for 30 seconds unilateral leg stand (right and left limb individually) was normalized to 100% for further analysis. To avoid excessive muscle excitation before PMT application, using unilateral leg stand was preferred over maximal voluntary contraction (MVC) tests of plantarflexion. Carrying out the MVC tests on a different day than the subjects were tested was impossible due to the time constraints of larger number of participants and laboratory schedule.

Standing Heel Raise Task

Participants stood barefoot with their feet as close as possible, but without feet, ankles or knees touching (Figure 1). Arms were relaxed and positioned next to the body. Participants started body weight heel raise on a verbal queue (“now”) in tempo of 2 seconds concentric and 2 seconds eccentric. The height of the heel raise performance

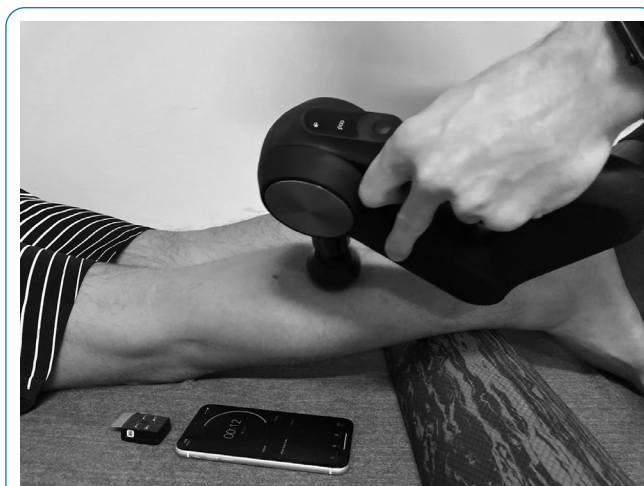


Figure 3. Percussion massage therapy application with massage gun.

was set as the maximal individual available position while maintaining stable posture without a step, fall, or another movement variation (Figure 2). A total of 4 standing heel raises trials, with 15 second rest in-between, were performed before and after the intervention. Mean result of peak RMS of all 4 trials was used for further analysis.

Intervention

Between pre and post-test, there was a one and half minute period during which each participant was in a prone position on a medical examination bed. The experimental PMT groups received a 30-second triceps surae massage on each limb, along the muscle fibre direction, moving from the Achilles tendon insertion upwards the muscle belly, repeatedly gliding at a controlled pace (~ 5 cm/sec) up and down the triceps surae complex, ensuring equal coverage of medial and lateral gastrocnemius, and soleus muscles, as per manufacturer instructions and previous research recommendations²⁴. While the control group maintained the same prone position without massage (Figure 3). The massage gun was set to 2100bpm and 1 bar of surface pressure was indicated by the device.

Statistical Analysis

Data distribution was assessed using the Shapiro-Wilk test for normality and Levene's test for homogeneity of variance. Most EMG variables were normally distributed ($p > 0.05$), with only one variable (post CAI-PMT) slightly violated normality borderline ($p = 0.049$). Levene's test indicated homogeneity of variance across pre-test groups ($p = 0.591$). Accordingly, data supported the use

Table 2. Results of Peak %RMS Prior to Percussion Massage Therapy Procedure.

	Peak %RMS (mean \pm SD)	Std. error mean	p-value	Cohen d	CI 95%
CAI	192.1 \pm 78.7	14.6	0.017	-0.75	-119.7, -12.5
CON	258.1 \pm 95.6	21.9			

Abbreviation: CAI (chronic ankle instability); CON (controls); PMT (percussion massage therapy); NOPMT (without percussion massage therapy); SD (standard deviation); CI (confidence interval).

of parametric tests for further analysis. Basic descriptive statistics (Mean \pm SD) were calculated for all variables. Extreme outlier values were adjusted to the value at 95th percentile of the group (two subjects in CAI and two subjects in CON). Independent sample t-tests were used to determine significant differences between CAI and controls, and paired sample t-tests were used to determine significant differences between pre- and post-intervention. Cohen's d was calculated to assess the magnitude of within-group and between-group differences (effect size). The probability of a type I error (alpha) was set at $p < 0.05$ with 95% confidence interval for all analysed parameters. Statistical analysis was performed using IBM SPSS v24 (Statistical Package for Social Sciences, Inc., Chicago, IL, USA).

Results

Data analysis in Table 2 showed a significantly lower calf muscle activation of 26% in the CAI compared to CON with large effect ($F = 1.327$, $df = 46$, $p = 0.012$) before the intervention. No significant difference was found between CAI-PMT and CAI-NOPMT, nor between CON-PMT and CON-NOPMT before or after the intervention.

Data analysis in Table 3 showed a significant lower calf muscle activation of 10% between pre and post-tests in CAI-PMT with moderate effect ($t = 2.291$; $df = 14$; $p < 0.05$) and 12% in CON-PMT with large effect ($t = 2.648$; $df = 8$; $p < 0.05$).

Discussion

The aim of this research was to examine the effect of PMT on calf muscle EMG activation patterns during a standing heel raise task in participants with a history of CAI and controls. The hypotheses were that individuals with CAI would have lower calf muscle activation during heel raise than controls. Furthermore, PMT would increase the peak

Table 3. Results of Peak %RMS in Pre and Post-Tests in Percussion Massage Therapy procedure.

	Peak %RMS (mean \pm SD)		Std. error mean		p-value	Cohen d	95% CI
	Pre	Post	Pre	Post			
CAI-PMT	199.9 \pm 84.9	181.0 \pm 83.8	21.9	21.6	0.038	0.59	1.2, 36.7
CAI-NOPMT	183.5 \pm 73.7	168.7 \pm 62.0	19.7	16.6	0.325	0.27	-16.5, 46.3
CON-PMT	257.2 \pm 69.6	225.1 \pm 74.6	23.2	24.9	0.029	0.88	4.2, 60.1
CON-NOPMT	258.8 \pm 118.1	267.2 \pm 102.1	37.4	32.3	0.255	-0.38	-23.8, 7.2

Abbreviation: CAI (chronic ankle instability); CON (controls); PMT (percussion massage therapy); NOPMT (without percussion massage therapy); SD (standard deviation); CI (confidence interval).

muscle activity in both groups in the post-therapy heel raise. It was found that individuals with a history of CAI did have significantly lower calf muscle activation than controls, supporting our first hypothesis. However, we did not support our second hypothesis, as we found that peak muscle activity was significantly decreased after the PMT intervention in both groups.

The decreased muscle activation observed immediately following PMT can be attributed to various physiological processes. PMT differs from typical massage in that it does not rely solely on stable pressure and friction. Mechanoreceptors, specifically Golgi tendon organs (GTOs), play an important role. GTOs are specialized sensory neurons that convert mechanical deformations (pressure/vibration) into electrochemical signals, and their functional characteristics determine the specific reflex response²⁵. PMT applies repetitive mechanical pressure to muscle and tendon structures, activating GTOs that generate afferent signals transmitted to the spinal cord^{25,26}. In the spinal cord, these signals interact with inhibitory interneurons that act upon alpha-motoneurons innervating the muscle. Inhibition of alpha-motoneurons can reduce tension and contraction, as demonstrated in various studies. Presynaptic inhibition plays a critical role in modifying the H-reflex, which is a measure of alpha-motoneuron excitability^{27,28}. In addition, the study by Maffiuletti et al.²⁹ supports the view that the mechanism for reflex facilitation involves a reduction in presynaptic inhibition of alpha motoneurons. Ellaway et al.³⁰ assert that early discharges in tendon organ afferents initiate inhibition, while tension-dependent discharges of tendon organs provide additional inhibition of gamma motoneurons, which are crucial for muscle contraction. In addition to GTO inhibition, PMT may alter corticospinal excitability, change fascial tension, or desensitize mechanoreceptors, all of which could contribute to the observed reduction in muscle activation^{31,32}.

Even though neural mechanisms appear primary, it is worth considering that metabolic factors may also contribute. Magnesium-bound adenosine diphosphate (MgADP) functions as an activator while inorganic

phosphate (Pi) acts as an inhibitor of tension development in single skeletal muscle fibres³³. These metabolic factors regulate muscle contraction and may contribute to the observed decrease in activation after PMT, although they were not directly measured in this study. Enriquez-Denton et al.³⁴ demonstrated the effect of presynaptic inhibition on excitatory postsynaptic potentials resulting from repetitive activation of peripheral afferents or fast and slow muscle stretch, providing strong evidence for the crucial role of inhibition in modulating muscle contraction³⁴.

Research in animals found that Ib autogenetic inhibition in motoneurons decreased during contractions of an ankle extensor muscle³⁵. In healthy humans, during sustained submaximal plantarflexion, subjects exhibit a reduction in recurrent inhibition of soleus alpha-motoneurons³⁶. Beyond muscles, these therapies also target the myofascial connective tissues, which may become rigid or adhered, especially in individuals with chronic overload or instability. Myofascial release techniques manual, foam rolling, or percussion aim to restore pliability and glide between fascial layers, reducing mechanical resistance and perceived pain. Emerging evidence supports actual structural changes in fascia following repetitive percussion therapy. A 2024 randomized controlled trial using ultrasound imaging in firefighters with chronic low back pain showed that six weeks of thrice-weekly percussion therapy significantly reduced echo intensity of the thoracolumbar fascia (TLF), a proxy for fibrotic changes and altered composition³⁷. Although TLF thickness did not significantly change, participants experienced less back pain, and improved functional scores compared to controls³⁷. These findings suggest that percussion therapy may “remodel” fascia by disrupting collagen cross-linking or increasing local perfusion, thereby relieving chronic fascial tension.

Although we hypothesized an increase in peak contraction in both controls and individuals with a history of CAI based on the claims of the PMT gun manufacturer, the body’s response to the stimulus was contrary, indicating that inhibitory mechanisms dominate acutely after PMT. Mechanoreceptors play a critical role in reflex responses and

modulation of motor activity, processing somatosensory information and the perception of touch and pressure in higher centres such as the somatosensory cortex²⁶. Beyond the immediate inhibitory effects of PMT, existing research also shows neuromuscular activation differences in individuals with CAI compared to healthy controls^{38,39}, indicating that reduced calf activation may be related to broader neuromuscular deficits rather than PMT alone. Athletes with CAI show decreased neuromuscular function and EMG activity in the peroneus longus muscle, as well as reduced strength in dorsiflexor muscles, compared to non-CAI athletes⁶. This is consistent with Koshino et al.⁴⁰ and Palmieri-Smith et al.⁴¹, who also reported lower peroneal muscle activity during walking gait in CAI patients. Our research supports these findings, as limbs with a history of CAI were found to have 26% less muscle activity during calf raising prior to PMT applications compared to limbs without CAI. Increased attention and interventions aimed at enhancing calf muscle activity during movement initiation or other dynamic tasks may be beneficial. Suggesting another possible impact of CAI on proximal muscle groups, Lee et al.⁴² reported decreased postural hip muscle activity. Research has also demonstrated an association between core muscle dysfunction and CAI, indicating differences in muscle activity and proximal segment kinematic patterns in individuals with CAI compared to healthy controls⁴³. Furthermore, Gribble et al.² found that CAI combined with fatigue induces proximal joint changes during performance, suggesting a broader effect on neuromuscular control beyond the ankle joint. Individuals with unilateral CAI also exhibit reduced eccentric torque production across the ankle, knee, and hip muscle groups, indicating a widespread impact on lower extremity muscle function³⁹. Additionally, patients with unilateral functional ankle instability exhibit weakness in the pronator muscles, reinforcing the notion of widespread neuromuscular deficits⁴⁴.

Pietrosimone et al.¹³ were the first to examine corticomotor excitability in subjects with CAI. Using transcranial magnetic stimulation, they determined that the CAI group had higher resting motor threshold values compared to controls in both lower limbs ($F_{1,18} = 4.92$, $p = 0.04$, $1-\beta = 0.56$). Furthermore, a correlation was observed between FADI (Functional Ankle Disability Index) scores and the resting motor threshold of the fibularis longus ($r = 0.4$, $r^2 = 0.16$, $p = 0.04$). Validated instruments such as CAIT or FADI were not utilized in the current study, and their inclusion is recommended in future CAI research classifications. Finally, PMT and other vibration-based modalities appear to exert a sensory-desensitization effect. Four-week lumbar PMT programs increased pressure-pain thresholds by >15 % and shortened subjective DOMS duration in resistance-trained individuals⁴⁵. Such analgesia likely stems from gate-control inhibition at the dorsal horn and may allow CAI patients to participate more fully in challenging drills⁴⁶. Taken together, these contributions offer a broader understanding of PMT's multifaceted effects and highlight several promising avenues for future investigation.

Limitations

Despite the data sample being close to the power analysis requirements, a larger number in experimental and control groups will strengthen the study. Another limitation is the analysis of only one of the three triceps surae muscles. While no clinical testing, imaging or standardized clinical questionnaires (CAIT) were used in our study to define CAI subjects in more detail, these methods are recommended in future studies. More detailed characterization and categorization based on the type of ankle injury should be considered in future research. Changes after PMT don't need to be necessarily observed just on muscles level. Abilities of advanced measuring methods allow us to observe changes in the higher centres of the nervous system like neural circuits from spinal cord, motor cortex, cerebellum, brainstem or basal ganglia. Also, longitudinal data of PMT use could lead to changes in movement stereotypes, changes in nerve tracts using diffusion MRI data, etc. These could all be areas of next research. Since the initial PMT may be uncomfortable, even bringing low to moderately painful experience in some cases, we hypothesize that repeated interventions can reduce an individual's perception to the stimulus and induce adaptations that cause different results in future research. While variables like sex, limb dominance, and sports background were recorded, no statistically significant differences were found across these groups, as previously confirmed by research^{47,48,49}. Future studies with higher power may further explore interaction effects. Other recommendations are to use various PMT procedures and movements within examination of PMT effectivity on muscle activation in various athletic and non-athletic population. Future research should also examine the effectiveness of various activation exercises following PMT, as well as their relationships.

Conclusion

Limbs that had CAI had significantly decreased calf muscle activation in comparison to controls. This injury-affected group may require interventions that enhance calf muscle activity prior or during movement activity. However, PMT may not be one of these interventions as it significantly lowered calf muscle activation after use. Its benefit may be more for recovery after exercise for users, or to not underestimate activation exercises when using PMT before performance. Researchers should use this novel for future research in analysing longitudinal use of PMT and its effects on further muscles and control centres.

Practical applications

It can be concluded that the use of percussion therapy as a pre-activation tool before sports performance may be counterproductive, as it has been demonstrated to reduce peak EMG activation. This phenomenon must be examined widely in conditioning, as these tools are used by

thousands of athletes and may have various psychological and physiological effects. Experienced coaches should communicate with their athletes and monitor whether the use of PMT tools is beneficial to overall performance, given the numerous interconnected factors involved. However, lower muscle activation before physical activity can diminish the readiness and responsiveness of the muscles, potentially impairing performance. Therefore, it is questioned whether athletes should avoid PMT in their warm-up routines, as it may undermine the intended effect of priming the muscles for action. Conversely, the reduction in muscle activation appears to make PMT an optimal choice for post-activity recovery. Following intense physical exertion, athletes may frequently experience muscle tension and soreness, which can impede recovery and affect subsequent performance. The application of percussion therapy after exercise can assist in relaxing the muscles, reducing soreness, and promoting a quicker recovery by decreasing muscle excitability and aiding in the relaxation process. This application is particularly beneficial for sports involving repeated high-intensity efforts, as it can help athletes maintain peak performance levels over time by optimising recovery. Thus, it seems that coaches may incorporate PMT into post-exercise routines to leverage its relaxation benefits and potential to reduce the risk of injury. An understanding of the optimal timing and utilisation of PMT can therefore inform the refinement of athlete preparation and recovery strategies, ensuring that they derive the maximum benefit from their training and competition. It is recommended that the muscle activation exercises and strategies employed following the PMT (if used before performance) are not underestimated, to ensure compensation for any lowered activation.

Ethics approval

The research was carried out by the Declaration of Helsinki and received ethical compliance according to the decision numbered 208/2022 and dated 22/11/2022 from Ethical Committee of Faculty of Physical Education and Sport, Charles University.

Consent to participate

Written informed consent was obtained from all participants.

Author's contributions

All authors contributed to the design, conceptions and implementation of the study. Data collection was performed by Lukas Michal and Mikulas Hank. Data analysis was performed by Mikulas Hank, Lukas Michal and Dai Sugimoto. Mikulas Hank, Lukas Michal and Ferdia Fallon Verbruggen wrote the first draft of the manuscript. Research process supervision and manuscript proofreading were carried out by Dai Sugimoto, Frantisek Zahalka and Tomas Maly. Additional writing of the original draft, final format editing and reference structures were carried out by Pavol Pivovarnicek and Petr Miratsky. All authors have read and approved the final manuscript.

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