Journal of Athletic Training 2024;59(3):310–316
doi: 10.4085/1062-6050-0041.23

www.natajournals.org

Under the Gun: Percussive Massage Therapy and Physical and Perceptual Recovery in Active Adults

Alana J. Leabeater, B Sport & Exercise Science (Hons); Anthea C. Clarke, PhD; Lachlan James, PhD; Minh Huynh, PhD; Matthew Driller, PhD

Sport, Performance and Nutrition Research Group, School of Allied Health, Human Services, and Sport, La Trobe University, Melbourne, Victoria, Australia

Context: Handheld percussive massage devices (ie, massage guns) are a relatively new and under-researched recovery tool. These tools are intended to increase range of motion and reduce muscle soreness by delivering targeted vibration to soft tissues. Empirical knowledge about the potential influence of these devices on perceptual recovery and the recovery of performance characteristics after exercise is scarce.

Objective: To investigate the effect of a 5-minute massage gun application, using a commercially available device, on physical and perceptual recovery after a strenuous bout of lower body exercise.

Design: Controlled laboratory study.

Setting: Physiology laboratory.

Patients or Other Participants: A total of 65 active young adults (age = 21.3 ± 1.4 years; age range = 18–30 years; 34 women: height = 165.8 ± 6.1 cm, mass = 66.0 ± 7.4 kg; 31 men: height = 181.1 ± 6.0 cm, mass = 81.5 ± 11.8 kg).

Intervention(s): Participants applied a massage gun on the calf muscles of 1 leg after strenuous exercise (massage gun recovery group) for 5 minutes and used no recovery intervention on the other leg (control group).

Main Outcome Measure(s): Ankle range of motion, calf circumference, isometric strength, calf endurance, and perceived muscle soreness measures were collected at baseline and at various points after lower body exercise.

Results: No significant group × time interactions were recorded for any of the performance or perceptual measures (P values > .05). Effect sizes were mostly unclear, except for a small increase in perceived muscle soreness in the massage gun recovery group compared with the control group immediately ($d = -0.35$) and 4 hours ($d = -0.48$) postrecovery.

Conclusions: Massage guns appeared to have little effect on physical measures when applied for 5 minutes immediately after strenuous calf exercise. Given the small increase in muscle soreness up to 4 hours after their use, caution is recommended when using massage guns immediately after strenuous lower body exercise.

Key Words: massage gun, vibration therapy, delayed-onset muscle soreness

Key Points

- Massage gun application had little effect on measures of ankle range of motion, calf circumference, isometric strength, or calf endurance when applied for 5 minutes after an intense bout of calf exercise.
- Small increases in perceived muscle soreness may occur up to 4 hours after use of massage guns.
- Caution may need to be taken when considering the application of these devices for lower body recovery immediately after strenuous exercise if the focus of recovery is to improve physical or perceptual measures in preparation for subsequent exercise.

Unfamiliar or intensive exercise can result in substantial musculoskeletal pain and discomfort, reduced range of motion, and decreased muscular force production, which may motivate athletes to seek out and implement recovery methods or routines.[1,2] Short-term recovery interventions, including foam rollers, cold-water immersion, and compression garments, offer a practical and time-efficient way to potentially reduce physical fatigue and thereby maintain the quality of subsequent training sessions.[1] One such category of recovery tool that has recently grown in popularity is handheld percussive massage devices (ie, massage guns). These battery-powered devices deliver vibrations at varying amplitudes and are purported to reduce perceived muscle soreness and improve lower limb mobility.[3] While a conventional sports massage commonly reduces symptoms of delayed-onset muscle soreness and may improve flexibility,[4] less is known about percussive massage devices and their potential influence on physical and perceptual recovery. However, massage guns appear to be both a popular and a well-regarded tool among athletes, with 15% to 25% of competitive triathletes using the devices in a regular training week.[5]

Although massage guns are predominantly marketed as a recovery tool, previous researchers have focused on applications of these devices pre-exercise or during rest periods between exercise bouts. For example, a 5-minute application of a massage gun to the calf muscles (gastrocnemius and soleus) improved dorsiflexion range of motion in recreational male athletes, although no improvements were shown in subsequent

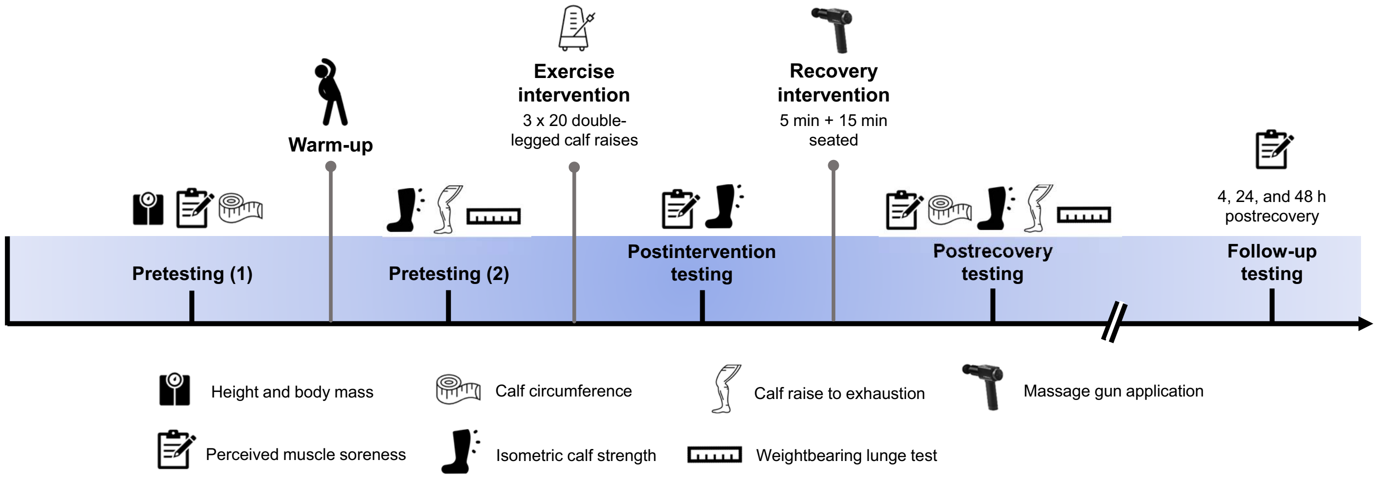

Figure 1. Testing timeline.

performance of an isometric dynamometry task.[6] Meanwhile, Kujala et al[7] reported that a 5-minute lower body application of a massage gun during a dynamic warm-up did not result in any changes to vertical jump height in trained men. However, the brand and vibration speed of the massage gun used was not provided. More recently, García-Sillero et al[8] showed that a 3-minute rest-period application of a massage gun to the pectoralis muscles after bench-press repetitions demonstrated benefits for restoring muscle compliance and reducing stiffness. The use of massage guns after strenuous exercise has been investigated in only 1 study: Alonso-Calvete et al[9] observed no changes to perceived fatigue and blood lactate in qualified lifeguards after a massage gun was applied for 8 minutes after a 200-m simulated water rescue. Nonetheless, as these were the only 2 variables considered, whether the use of the massage gun could have influenced performance measures (eg, swim rescue time) is unknown.

Conversely, serious illnesses that occurred after massage gun use have been described in 2 case reports. Chen et al[10] described a case of rhabdomyolysis (severe illness caused by the breakdown of skeletal muscle fibers into the bloodstream) after a coach's application of a massage gun for 10 minutes on a young adult female athlete who had recently finished a light gymnasium cycling session. More recently, Masters et al[11] noted a case of hemothorax (collection of blood in the pleural cavity, usually from blunt force trauma) in a man after "regular" use of a massage gun to the chest and back. These cases highlight the potential safety risks associated with massage guns that may occur from both infrequent and regular use of the devices. The scarcity of empirical literature in this area, in addition to the lack of evidence-based guidelines for the use of massage guns, emphasizes the need for further research and caution regarding the potentially adverse effects of their use.

The recent growth in popularity of massage guns may be explained by the idea that athletes tend to select recovery strategies based on perceptions associated with the use of that strategy rather than its effectiveness at a physiological level.[12] Therefore, the prospect of reduced muscle soreness and tightness after use is likely the most appealing aspect of these devices. In addition, the use and promotion of such novel devices by elite athletes may contribute to greater perceived effectiveness of the devices among athletes at lower competition levels.[12] Clearly, examinations of the effect of massage guns on physiological or perceptual recovery after strenuous exercise are scarce. Thus, the purpose of our study was to evaluate the effect of a 5-minute massage gun application on perceptual and physical recovery after strenuous lower limb exercise. We hypothesized that the acute massage gun application would reduce perceived muscle soreness and improve recovery of physical performance after strenuous lower body exercise.

METHODS

Design

We adopted a repeated-measures, single-group design that implemented an experimental leg (massage gun recovery [GUN]) and a control leg (passive recovery [CON]). Participants were allocated experimental and control legs in a randomized, counterbalanced design. They completed physical and perceptual measures at various times before and after lower limb exercise and after the recovery intervention (Figure 1). Participants completed all testing within a 1.5-hour period and were asked to refrain from strenuous lower body exercise for 24 hours before and 24 hours after the study to limit any influence on physical testing or muscle soreness measures.

Participants

A total of 65 active young adults (age = 21.3 ± 1.4 years; age range = 18–30 years; 34 women: height = 165.8 ± 6.1 cm, mass = 66.0 ± 7.4 kg; 31 men: height = 181.1 ± 6.0 cm, mass = 81.5 ± 11.8 kg) volunteered. Participants were recruited through a university sport science undergraduate program. All volunteers were active in regular physical exercise sessions (approximately 3 times per week) and were free from lower limb injuries (hip, knee, or ankle) that might have affected their ability to perform the physical tests or exercise protocol. All participants provided written informed consent, and the study was approved by the La Trobe University Human Research Ethics Committee.

Procedures

Belief Effect. Before the testing session, participants rated their perception of whether "massage guns will improve

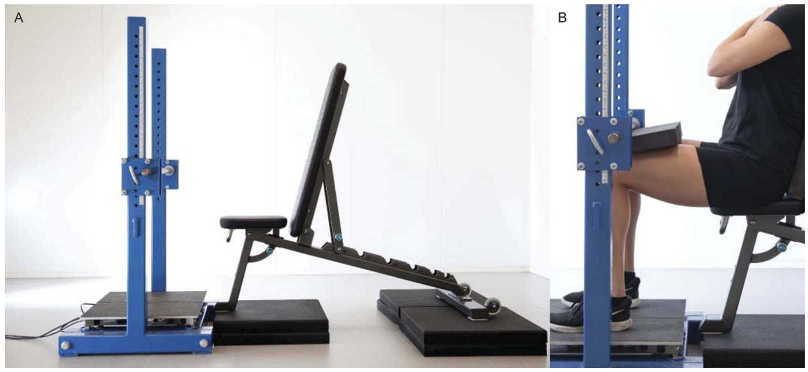

Figure 2. A, Isometric calf-raise rig setup without participant. B, Participant applying a plantar-flexion force and pressing the knees into a foam pad below a rigid bar.

recovery following exercise" on a continuous, 10-cm visual analog scale, ranging from *strongly disagree* (0 cm) to *strongly agree* (10 cm). Participants were then categorized as having *high belief* or *low belief* based on a cut-off of 5 cm on this scale, as used previously.[13] Care was taken throughout the testing session to not influence participants' perceptions of the use of massage guns.

Weight-Bearing Lunge Test. The weight-bearing lunge test (WBLT) was performed as a measure of dorsiflexion range of motion of each ankle at baseline and after recovery. Previous investigators have reported robust interrater and intrarater reliability associated with the assessment of WBLT performance in healthy adults, with high levels of test-retest reliability demonstrated (standard error of measurement [SEM] = 1.1°, 95% CI = ±2.2°).[14] The baseline measurement was collected after a dynamic warm-up consisting of 5 minutes of single- and double-legged calf raises, ballistic bounces, and ankle circles. Participants placed the foot along a measuring tape that was secured to the floor and aligned perpendicular to a wall, with both the toe and heel on the center line of the measuring tape. They were then instructed to progressively move the toe farther back from the wall on the measuring tape, repeating the lunge movement until the maximum distance at which they could tolerably lunge their knee to the wall without lifting the heel. Using the tape measure, we determined the distance from the tip of the big toe to the wall (in centimeters).

Calf Circumference. A nonstretch anthropometric measuring tape (model Lufkin Executive Thinline) was used to measure the circumference of the lower leg at baseline and after recovery. This measurement allowed assessment of any lower limb swelling associated with the exercise recovery intervention. The landmark was the widest girth of the calf muscle. A permanent marker was used to indicate the measurement site and ensure high levels of test-retest reliability across time (Figure 1). This method of assessing calf circumference has been shown to have high reliability (SEM = 0.5–0.6 cm; intraclass correlation coefficient [ICC] = 0.97)[15] and to correlate with muscle volume ($R^2 = 0.42$).[16]

Isometric Calf-Raise Strength. A custom-built isometric calf-raise rig housing a dual force-platform system (model FDLite Dual Force Platform; VALD Performance; Figure 2A) was used to obtain left- and right-leg isometric strength measurements at baseline, postexercise, and postrecovery. This method has demonstrated high reliability (ICC = 0.94; coefficient of variation = 6.1%) for bilateral assessment of plantar-flexion strength.[17] Participants were seated on an adjustable-weight bench centered between the force platforms and maintained hip and knee flexion at 90° with their feet hip-width apart and centered on each platform. A soft foam pad was placed over their knees for comfort during testing. The researcher (A.J.L.) then adjusted the metal bar until it was firmly resting on the foam pad centered over the knees and secured the bar position with crocodile pins on the racking system. The bar height was recorded and repeated for subsequent testing. Participants were instructed to cross their hands over their shoulders and maintain an upright, vertical posture during isometric calf-raise testing. They were directed to perform maximal plantar flexion, pushing against the foam pad on top of their knees (Figure 2B) after an oral "3, 2, 1" countdown, as described earlier.[18,19] Before the first test, participants completed 2 warm-up efforts corresponding to 50% and 75% effort to familiarize themselves with the movement and bar position. They then performed 3 maximal isometric calf raises, holding each for 3 seconds, with a 10-second rest between raises. They were orally encouraged in the same manner during each repetition to exert maximal force production. Data were recorded using ForceDecks (VALD Performance) software and split into bilateral data obtained from each person's left and right limbs for analysis.

Single-Legged Calf Raise to Exhaustion. A single-legged calf-raise test to exhaustion was performed pre-exercise (baseline) and postrecovery to assess the strength endurance of the calf muscles. The calf raises were completed in time with a metronome set at 60 beats per minute, with a 1-minute rest between limbs. The testing order for each leg (CON versus GUN) was randomized across participants but was kept the same for each individual. Starting position involved the participant standing on 1 limb, with the ankle in neutral position (0°) and the knee at full extension. The individual was instructed to complete as many repetitions of a single-legged calf raise (as high as possible or maximum range of motion) as possible. Using the fingers on a wall to balance was allowed but without applying any downward pressure on the wall to assist the movement. The 2 criteria for terminating the test were not completing a full range-of-motion calf-raise repetition in time with the metronome or volitional exhaustion. The test-retest reliability of the calf-raise test has been described in healthy adults and deemed highly reliable, with ICCs ranging from 0.78 to 0.99 and SEMs ranging from 2 to 6 repetitions.[20–25]

Perceived Muscle Soreness. Participants rated their perceived muscle soreness for each limb on a scale of 1 (*no soreness*) to

10 (*maximal soreness*).[26] Ratings were obtained while they performed a single-legged calf raise on each side. For the 4-, 24-, and 48-hour postrecovery times, each person was sent an electronic survey link (QuestionPro) via anonymized text message, which contained the same instructions for completing the perceived muscle soreness scale for each limb.

Exercise Intervention. The exercise bout used to induce fatigue and subsequent muscle soreness was targeted at the calf muscles. Participants were instructed to complete 3 sets of 20 double-legged calf raises at full range of motion off a 30-cm-high platform in time with a metronome set at 60 beats per minute and with a 1-minute rest between sets. They were allowed to use their fingers on a wall to balance but not to apply any downward pressure on the wall to assist their movement.

Massage Gun Recovery. Immediately after the postexercise testing time point, participants performed a recovery intervention on 1 limb (GUN) while the other limb had no recovery intervention (CON). The recovery intervention involved a 5-minute treatment to the calf muscles using a massage gun device (Hydragun) with a soft attachment head. The massage gun device was used at a speed of 53 Hz, or approximately 3200 rpm, as reported previously.[6] Participants were instructed to apply the massage gun to a relaxed calf muscle while seated. The medial gastrocnemius was the focus for the first half of the 5 minutes of the massage treatment and then the lateral gastrocnemius muscle for the second half. As per the manufacturer's instructions, they were directed to "glide" the massage gun along the muscle belly continuously at the selected device speed.[27] After the 5-minute treatment, participants remained seated for a further 15 minutes before performing the postrecovery tests (Figure 1).

Statistical Analysis

Descriptive statistics (means and SDs) for the WBLT (in centimeters), calf circumference (in centimeters), isometric net peak force (in newtons), isometric net force at 100 and 200 milliseconds (in newtons), calf-raise repetitions (number), and perceived muscle soreness (in arbitrary units [AUs]) were computed for the various times. A linear mixed model (LMM) was conducted to examine the effects of the recovery intervention (GUN versus CON) on these measures. The LMM consisted of a fixed effect of time (2 to 6 levels, depending on the variable) and a random intercept for participant identifier. We assessed normality via a visual inspection of a Q-to-Q plot and deemed the residuals to approximate a normal distribution. No interaction effect was recorded for time × intervention for any of the testing measures; thus, the model was refit without the interaction term. The mean differences in the outcomes from baseline level to each time were calculated, and 95% CIs were calculated to denote the imprecision of model parameter estimates.

A sensitivity analysis via a 2-way repeated-measures analysis of variance was also computed to ensure that the results of the LMM were robust. All data are presented as mean ± SD unless otherwise stated. In addition, we determined effect size statistics to evaluate differences between the GUN and CON groups at each time. For these measures, the standardized change in mean between times was identified and expressed as standardized (Cohen *d*) effects and 95% CIs. The magnitude of each effect size was interpreted using thresholds of 0.2, 0.5, and 0.8 for *small*, *moderate*, and *large*, respectively.[28] An effect size of <0.2 was considered *trivial*. Where the 95% confidence limits overlapped the thresholds for small positive and small negative values, the effect was considered *unclear*. All statistical analyses were conducted using the Jamovi statistical package (version 1.8.1; Jamovi Project, 2021), and $P \leq .05$ indicated a difference.

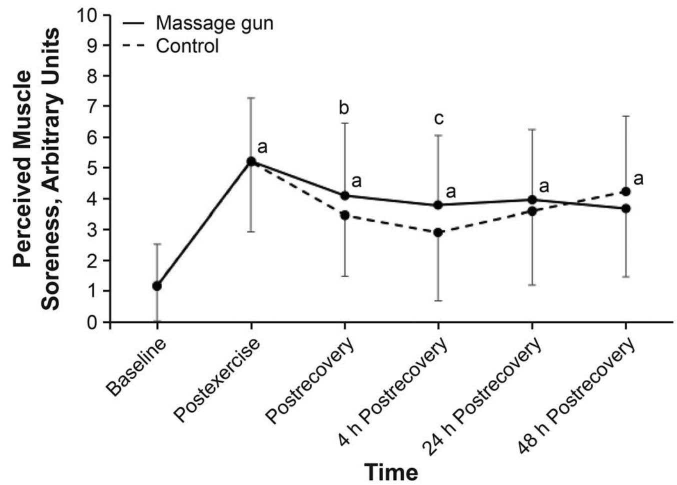

Figure 3. Changes in perceived muscle soreness over a 48-hour period after strenuous exercise in the control and massage gun recovery interventions. [a] Difference in perceived muscle soreness for both groups compared with baseline (*P* < .05). [b] Small effect size in the massage gun compared with the control recovery group (−0.35 ± 0.35). [c] Small effect size in the massage gun compared with the control recovery group (−0.48 ± 0.39).

RESULTS

We observed no interaction between group and time for perceived muscle soreness ($F_{5,582} = 1.69$, $P = .14$). However, we found a main effect of time on perceived muscle soreness ($F_{5,591} = 64.77$, $P < .001$), as perceived muscle soreness increased at each respective time compared with baseline. Perceived muscle soreness was greater by 2.5 AU (95% CI = 1.90, 3.08 AU; $t_{609} = 8.30$; $P < .001$) at the 48-hour follow-up versus baseline. We noted a small difference in that perceived muscle soreness was greater in the GUN group compared with the CON group immediately postrecovery (−0.35 ± 0.35 AU) and at 4 hours postrecovery (−0.48 ± 0.39 AU; Figure 3).

The results of the 2-way repeated-measures analysis of variance for the remaining dependent variables were consistent with those of the LMM. No interaction was evident between group and time for the WBLT ($F_{1,126} = 0.317$, $P = .57$, $\eta^2_p = 0.003$), calf circumference ($F_{1,126} = 0.431$, $P = .51$, $\eta^2_p = 0.003$), and single-legged calf raises to exhaustion ($F_{1,126} = 0.494$, $P = .48$, $\eta^2_p = 0.004$), with unclear effect sizes (Table). In addition, we demonstrated no interaction between group and time for isometric peak net calf-raise force ($F_{1,122} = 0.0301$, $P = .97$, $\eta^2_p = 0.000$), isometric net vertical force at 100 milliseconds ($F_{1,122} = 0.124$, $P = .88$, $\eta^2_p = 0.001$), and isometric net vertical force at 200 milliseconds ($F_{1,122} = 0.00662$, $P = .94$, $\eta^2_p = 0.001$), with unclear effect sizes. However, a main effect of time was present for both calf circumference ($F_{1,126} = 39.409$, $P < .001$) and calf endurance ($F_{1,126} = 26.604$, $P < .001$). Specifically, calf circumference was greater at postrecovery (37.3 cm; range = 36.9–37.8 cm) than baseline (36.9 cm; range = 36.4–37.4 cm), Table. Summary of Measures for the Control and Massage Gun Conditions

Measure and Time	Condition, Mean ± SD		Group × Time Interaction	
	Control	Massage Gun	*P* Value	Effect Size *d* ± 95% CI; Interpretation[a]
Weight-bearing lunge test, cm			.57	
Baseline	11.1 ± 3.5	11.4 ± 3.4		
Postrecovery	11.1 ± 3.7	11.1 ± 3.5		−0.03 ± 0.10; unclear
Calf circumference, cm			.51	
Baseline	36.8 ± 2.7	37.0 ± 2.8		
Postrecovery	37.3 ± 2.7	37.4 ± 2.8		−0.03 ± 0.09; unclear
Net vertical force at 100 ms, N			.88	
Baseline	129.6 ± 69.8	121.9 ± 75.8		
Postexercise	139.6 ± 62.8	136.7 ± 68.3		−0.07 ± 0.27; unclear
Postrecovery	135.0 ± 66.7	131.6 ± 62.7		−0.06 ± 0.25; unclear
Net vertical force at 200 ms, N			.94	
Baseline	373.5 ± 163.4	355.8 ± 164.1		
Postexercise	407.5 ± 171.7	398.9 ± 169.6		−0.05 ± 0.26; unclear
Postrecovery	397.7 ± 164.1	385.7 ± 154.7		−0.03 ± 0.25; unclear
Peak net vertical force, N			.97	
Baseline	830.1 ± 309.5	799.6 ± 290.4		
Postexercise	854.7 ± 338.4	828 ± 311.1		−0.02 ± 0.24; unclear
Postrecovery	859.3 ± 312.5	836.6 ± 295.1		−0.03 ± 0.20; unclear
Single-legged calf raise to exhaustion, No. completed			.48	
Baseline	37.6 ± 14.2	39.5 ± 17.2		
Postrecovery	33.2 ± 13.7	33.7 ± 14.0		−0.02 ± 0.37; unclear
Perceived muscle soreness, arbitrary units			.14	
Baseline	1.2 ± 1.4	1.2 ± 1.4		
Postexercise	5.2 ± 2.3	5.2 ± 2.1		−0.02 ± 0.37; unclear
Postrecovery	3.5 ± 2.0	4.1 ± 2.4		−0.35 ± 0.35; small
4 h Postrecovery	2.9 ± 2.2	3.8 ± 2.3		−0.48 ± 0.39; small
24 h Postrecovery	3.6 ± 2.4	4.0 ± 2.3		−0.24 ± 0.45; unclear
48 h Postrecovery	4.2 ± 2.5	3.7 ± 2.2		−0.23 ± 0.60; unclear

[a] The magnitude of the effect size was interpreted using thresholds of 0.2 (*small*), 0.5 (*moderate*), and 0.8 (*large*). Where the 95% confidence limits overlapped the thresholds for small positive and small negative values, the effect was considered *unclear.*

and the number of calf raises completed was lower at postrecovery (n = 34; range = 31–36) than baseline (n = 39; range = 36–41).

When we categorized participants by their belief in the effectiveness of massage guns as a recovery intervention, 46 respondents (70.8%) had *high belief* (>5 cm on the visual analog scale) compared with 17 (26.2%) who had *low belief* (≤5 cm on the visual analog scale); 2 participants did not provide a response to this question. No main effect of belief on perceived muscle soreness was recorded.

DISCUSSION

The purpose of our study was to evaluate the effects of a short application of a massage gun to the calf muscles on perceptual and physical recovery after strenuous lower body exercise. A 5-minute application of a commercially available massage gun immediately after an exercise task had little effect on measures of ankle range of motion, calf circumference, isometric strength, or calf endurance. However, the use of these devices for acute recovery may result in a small increase in perceived muscle soreness in the 4 hours after use, although this finding was not statistically significant. In addition, we observed no effect of prior belief in the effectiveness of massage guns on their effectiveness for recovery. To our knowledge, we are the first to report on the use of massage guns immediately after strenuous lower limb bodyweight resistance exercise, showing they may have limited effect on perceived muscle soreness and other measures of performance recovery over a short-term timeframe.

Our main outcome was that massage guns did not appear to improve physical recovery after intense lower body exercise compared with a passive control condition. This result agrees with that of Alonso-Calvete et al,[9] who observed no change in perceived fatigue and blood lactate with the use of a massage gun for 8 minutes after simulated water rescues in lifeguards. Although not directly comparable, similar investigations with 10 to 30 minutes of massage therapy immediately after strenuous running also demonstrated no effect on muscle soreness or muscle function (squat and drop jumps)[29] and no effect on quadriceps flexibility, isometric knee-extensor strength, or perceived fatigue.[30] In comparison, vibrating foam rollers improved range of motion, countermovement jump height, and muscle soreness after eccentric lower body exercise,[31,32] which may be related to increased body temperature and improved blood flow. Specific to our study, a 5-minute application of a massage gun appeared to offer no benefit in the recovery of calf muscle strength, range of motion, and endurance compared with a control condition of 20 minutes of passive recovery. Although this is a short timeframe in which to apply the selected recovery intervention and complete posttesting, it is also consistent with the recommended timing of use directed by massage gun manufacturers (eg, ≤2 minutes per muscle group at 1 time[33]), despite the unclear basis for this recommendation. Presently, insufficient evidence is available to recommend the short-term use of massage guns for the recovery of lower limb range of motion, strength, and endurance after strenuous exercise versus a rest condition. As such, these devices may not be an ideal recovery intervention between lower body training sessions on the same day. However, whether this acute use of massage guns may have a different effect on physical factors across a longer timeframe (eg, post-testing 24 hours later) is unknown. In the future, researchers could examine muscle blood flow and oxygen saturation with the use of massage guns, as has been done with vibrating foam rollers,[32] to further elucidate any physiological changes (or lack thereof) with these devices.

An unexpected observation in this study was the small increase in perceived muscle soreness observed immediately after recovery and 4 hours after recovery in the GUN group. In comparison, forms of vibration therapy such as vibrating foam rollers reduced perceived pain after fatiguing eccentric exercise, which may be related to increased local skin temperature and blood flow.[32] Yet handheld percussive massage therapy is distinct from both massage and vibration therapy in its amplitude, frequency, and direction of pressure, as the rapid and powerful stimulus can be applied in any direction at the will of the user. This more forceful manipulation of muscle tissues may stimulate mechanoreceptor nerve endings,[34] resulting in greater perceived muscle soreness immediately after application of the massage gun. However, this response appears to only be short term, as perceived muscle soreness at the 24- and 48-hour time points was not different between groups. It is also possible that the high frequency selected for the massage guns (approximately 53 Hz per Konrad et al[6]) was a factor in this small increase in perceived muscle soreness, as there may be individual variations in tolerance to massage gun speed and amplitude, which requires further investigation. Similarly, individuals demonstrated different pressure-pain thresholds and response patterns to traditional sport massage, which contributes to the perceived effectiveness of this recovery strategy.[35] Given that participants may not have been familiar with use of the massage guns and their effects, there is also the possibility that increased tolerance and reduced discomfort may occur with repeated use of the devices, as has occurred with deep-pressure massage.[36] Nonetheless, when considering this finding in conjunction with previous case reports of serious medical incidents from massage guns,[10,11] such devices should be used with caution and only as tolerated by the individual user.

Researchers investigating recovery interventions have previously considered the influence of prior belief on the effectiveness of the intervention.[13,37,38] One example involves compression socks, whereby runners who strongly believed in the effectiveness of compression socks displayed improved 5-km time trial performance after wearing the garments for recovery.[13] In our study, almost three-quarters of the participants were categorized as having high belief in the effectiveness of massage guns as a recovery intervention. Coaches, fellow athletes, and websites, rather than research articles or practitioners,[37] are the main sources of recovery information and recommendations for athletes, which may explain the high belief in the effectiveness of these devices in the absence of scientific evidence. Despite this, we saw no significant changes in either perceptual or physical measures between those with high belief versus low belief. Although a positive psychological perception did not influence the effectiveness of massage guns in this case, it may be important to consider in future investigations as a means of explaining variances in responses among participants.

Several limitations should be considered when interpreting our results. First, given the scarcity of existing literature on massage guns, no consensus exists on ideal vibration speed or amplitude for their use and whether this may differ depending on the timing of use (eg, pre-exercise or postexercise). Additionally, the participants' previous experience with massage guns was not obtained before testing, which may have influenced their use and perception of the devices during the recovery intervention. Second, participants' dietary intake was not tracked or controlled before the study or during the 48-hour follow-up period, which may have influenced muscular recovery. It is also possible that a systemic healing response to strenuous exercise occurred and influenced the interpretation of results from a "control leg" and an "experimental leg." Furthermore, perceived muscle soreness varies across muscle groups,[39] justifying the need for further examination of the application of massage guns after strenuous exercise targeting muscle groups other than the calf muscles.

CONCLUSIONS

Handheld percussive massage therapy is a relatively new and under-researched recovery tool that is intended to increase range of motion and reduce muscle soreness by delivering targeted vibration to soft tissues. Our findings indicate that massage guns had little effect on measures of ankle range of motion, calf circumference, isometric strength, or calf endurance when applied for 5 minutes after an intense bout of calf exercise. Moreover, small increases may occur in perceived muscle soreness up to 4 hours after use, although the finding was not statistically significant. Therefore, caution may need to be taken when considering the application of these devices for lower body recovery immediately after strenuous exercise if the focus of recovery is to improve physical, perceptual, or both measures in preparation for subsequent exercise.

ACKNOWLEDGMENTS

We thank Ketha Ledchumanasarma for his assistance with photography.

REFERENCES

1. Kellmann M, Bertollo M, Bosquet L, et al. Recovery and performance in sport: consensus statement. *Int J Sports Physiol Perform.* 2018;13(2):240–245. doi:10.1123/ijspp.2017-0759
2. Kristensen NS, Hertel E, Skadhauge CH, Kronborg SH, Petersen KK, McPhee ME. Psychophysical predictors of experimental muscle pain intensity following fatiguing calf exercise. *PloS One.* 2021;16(7):e0253945. doi:10.1371/journal.pone.0253945
3. Martin J. A critical evaluation of percussion massage gun devices as a rehabilitation tool focusing on lower limb mobility: a literature review. *SportRxiv Preprints*. January 20, 2021. doi:10.31236/osf.io/j9ya8
4. Davis HL, Alabed S, Chico TJA. Effect of sports massage on performance and recovery: a systematic review and meta-analysis. *BMJ Open Sport Exerc Med.* 2020;6(1):e000614. doi:10.1136/bmjsem-2019-000614
5. Leabeater AJ, James LP, Huynh M, Vleck V, Plews DJ, Driller MW. All the gear: the prevalence and perceived effectiveness of recovery strategies used by triathletes. *Perform Enhanc Health.* 2022;10(4):100235. doi:10.1016/j.peh.2022.100235
6. Konrad A, Glashüttner C, Reiner MM, Bernsteiner D, Tilp M. The acute effects of a percussive massage treatment with a hypervolt

device on plantar flexor muscles' range of motion and performance. *J Sports Sci Med.* 2020;19(4):690–694.
7. Kujala RP, Davis CD, Young L. The effect of handheld percussion treatment on vertical jump height. *Int J Exerc Sci Conf Proc*. 2019;8(7):75.
8. García-Sillero M, Jurado-Castro JM, Benítez-Porres J, Vargas-Molina S. Acute effects of a percussive massage treatment on movement velocity during resistance training. *Int J Environ Res Public Health.* 2021;18(15):7726. doi:10.3390/ijerph18157726
9. Alonso-Calvete A, Lorenzo-Martínez M, Pérez-Ferreirós A, et al. Why percussive massage therapy does not improve recovery after a water rescue? A preliminary study with lifeguards. *Healthcare (Basel).* 2022;10(4):693. doi:10.3390/healthcare10040693
10. Chen J, Zhang F, Chen H, Pan H. Rhabdomyolysis after the use of percussion massage gun: a case report. *Phys Ther.* 2021;101(1): pzaa199. doi:10.1093/ptj/pzaa199
11. Masters A, Duarte R, Chiang B, Sarvottam K, Patel K. Hemothorax after use of percussion massage gun: a case report. Poster presented at: American Thoracic Society Conference; May 17, 2022; San Francisco, CA. doi:10.1164/ajrccm-conference.2022.205.1_MeetingAbstracts.A4172
12. Crowther F, Sealey R, Crowe M, Edwards A, Halson S. Team sport athletes' perceptions and use of recovery strategies: a mixed-methods survey study. *BMC Sports Sci Med Rehabil.* 2017;9:6. doi:10.1186/s13102-017-0071-3
13. Brophy-Williams N, Driller MW, Kitic CM, Fell JW, Halson SL. Effect of compression socks worn between repeated maximal running bouts. *Int J Sports Physiol Perf.* 2017;12(5):621–627. doi:10.1123/ijspp.2016-0162
14. Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly D, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother.* 1998;44(3): 175–180. doi:10.1016/s0004-9514(14)60377-9
15. Carmont MR, Silbernagel KG, Mathy A, Mulji Y, Karlsson J, Maffulli N. Reliability of Achilles tendon resting angle and calf circumference measurement techniques. *Foot Ankle Surg.* 2013;19(4):245–249. doi:10.1016/j.fas.2013.06.007
16. Rosso C, Vavken P, Polzer C, et al. Long-term outcomes of muscle volume and Achilles tendon length after Achilles tendon ruptures. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(6):1369–1377. doi:10.1007/s00167-013-2407-1
17. Mattiussi AM, Shaw JW, Cohen DD, et al. Reliability, variability, and minimal detectable change of bilateral and unilateral lower extremity isometric force tests. *J Sport Exerc Sci.* 2022;6(3):191–199. doi:10.36905/jses.2022.03.05
18. Warneke K, Keiner M, Lohmann LH, Hillebrecht M, Wirth K, Schiemann S. The influence of maximum strength performance in seated calf raises on counter movement jump and squat jump in elite junior basketball players. *Sport Mont J.* 2022;20(2):63–68. doi:10.26773/smj.220610
19. Rhodes D, Jeffery J, Brook-Sutton D, Alexander J. Test-retest reliability of the isometric soleus strength test in elite male academy footballers. *Int J Sports Phys Ther.* 2022;17(2):286–292. doi:10.26603/001c.31047
20. Hébert-Losier K, Wessman C, Alricsson M, Svantesson U. Updated reliability and normative values for the standing heel-rise test in healthy adults. *Physiotherapy.* 2017;103(4):446–452. doi:10.1016/j.physio.2017.03.002
21. Yocum A, McCoy SW, Bjornson KF, Mullens P, Burton GN. Reliability and validity of the standing heel-rise test. *Phys Occup Ther Pediatr.* 2010;30(3):190–204. doi:10.3109/01942631003761380
22. Haber M, Golan E, Azoulay L, Kahn SR, Shrier I. Reliability of a device measuring triceps surae muscle fatigability. *Br J Sports Med.* 2004;38(2):163–167. doi:10.1136/bjsm.2002.002899
23. Ross MD, Fontenot EG. Test–retest reliability of the standing heel-rise test. *J Sport Rehabil*. 2000;9(2):117–123. doi:10.1123/jsr.9.2.117
24. Sman AD, Hiller CE, Imer A, Ocsing A, Burns J, Refshauge KM. Design and reliability of a novel heel rise test measuring device for plantarflexion endurance. *Biomed Res Int*. 2014;2014:391646. doi:10.1155/2014/391646
25. Möller M, Lind K, Styf J, Karlsson J. The reliability of isokinetic testing of the ankle joint and a heel-raise test for endurance. *Knee Surg Sports Traumatol Arthrosc*. 2005;13(1):60–71. doi:10.1007/s00167-003-0441-0
26. Thompson D, Nicholas C, Williams C. Muscular soreness following prolonged intermittent high-intensity shuttle running. *J Sports Sci.* 1999;17(5):387–395. doi:10.1080/026404199365902
27. How to use the hydragun deep tissue massage gun. Hydragun. Published May 20, 2021. Accessed September 6, 2022. https://blog.hydragun.com/how-to-use-hydragun-deep-tissue-massage-gun/
28. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd rev ed. Routledge; 2013.
29. White GE, West SL, Caterini JE, Di Battista AP, Rhind SG, Wells GD. Massage therapy modulates inflammatory mediators following sprint exercise in healthy male athletes. *J Funct Morphol Kinesiol.* 2020;5(1):9. doi:10.3390/jfmk5010009
30. Bender PU, Luz CMD, Feldkircher JM, Nunes GS. Massage therapy slightly decreased pain intensity after habitual running, but had no effect on fatigue, mood or physical performance: a randomised trial. *J Physiother.* 2019;65(2):75–80. doi:10.1016/j.jphys.2019.02.006
31. Kasahara K, Yoshida R, Yahata K, et al. Comparison of the acute effects of foam rolling with high and low vibration frequencies on eccentrically damaged muscle. *J Sports Sci Med.* 2022;21(1):112–119. doi:10.52082/jssm.2022.112
32. Romero-Moraleda B, González-García J, Cuéllar-Rayo Á, Balsalobre-Fernández C, Muñoz-García D, Morencos E. Effects of vibration and non-vibration foam rolling on recovery after exercise with induced muscle damage. *J Sports Sci Med.* 2019;18(1):172–180.
33. How long should I use my theragun? Therbody. Accessed November 1, 2022. https://www.therabody.com/anz/en-au/faq/getting-started/faq-category-1-faq-2.html#:∼:text=Depending%20on%20the%20desired%20result,2%2D3%20times%20per%20day
34. Lewis PB, Ruby D, Bush-Joseph CA. Muscle soreness and delayed-onset muscle soreness. *Clin Sports Med.* 2012;31(2):255–262. doi:10.1016/j.csm.2011.09.009
35. Weerapong P, Hume PA, Kolt GS. The mechanisms of massage and effects on performance, muscle recovery and injury prevention. *Sports Med.* 2005;35(3):235–256. doi:10.2165/00007256-200535030-00004
36. Wilson AT, Riley JL III, Bishop MD, et al. A psychophysical study comparing massage to conditioned pain modulation: a single blind randomized controlled trial in healthy participants. *J Bodyw Mov Ther.* 2021;27:426–435. doi:10.1016/j.jbmt.2021.02.014
37. Braun-Trocchio R, Graybeal AJ, Kreutzer A, et al. Recovery strategies in endurance athletes. *J Funct Morphol Kinesiol.* 2022;7(1):22. doi:10.3390/jfmk7010022
38. Stickford AS, Chapman RF, Johnston JD, Stager JM. Lower-leg compression, running mechanics, and economy in trained distance runners. *Int J Sports Physiol Perform.* 2015;10(1):76–83. doi:10.1123/ijspp.2014-0003
39. Schoenfeld BJ, Contreras B. Is postexercise muscle soreness a valid indicator of muscular adaptations? *Strength Cond J.* 2013;35(5):16–21. doi:10.1519/SSC.0b013e3182a61820

Address correspondence to Alana J. Leabeater, B Sport & Exercise Science (Hons), Sport, Performance and Nutrition Research Group, School of Allied Health, Human Services, and Sport, La Trobe University, Plenty Road and Kingsbury Drive, Bundoora, Melbourne, Victoria 3086, Australia. Address email to A.Leabeater@latrobe.edu.au.