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REPEATED MEASURES-RANDOMIZED, WITHIN-SUBJECTS

Use of Topical Analgesic and Rolling Alone or in Combination Does Not Increase Flexibility, Pain Pressure Threshold, and Fatigue Endurance—A Repeated-Measures Randomized, Within-Subjects, Exploratory Study

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Background: Prior studies have reported an increase in range of motion (ROM) and pain pressure thresholds (PPT) with self-massage using foam rollers and roller massagers. A possible mechanism for the increased ROM is the increase in stretch (pain) threshold. The effects of the use of a topical analgesic alone or in combination with rolling may provide additional benefits for ROM and PPT and improve the ability to tolerate discomfort during a fatiguing protocol.
Purpose: The purpose of this study is to investigate the effect of the use of a topical analgesic alone or a roller massager alone and a combination of both on ROM, PPT, and performance in a fatiguing protocol.
Design: This study used a repeated-measures, randomized, within-subjects design.
Methods: Sixteen healthy, active male participants (age range, 18–27 years) free from musculoskeletal injuries participated in the study that included 5 conditions, namely, control, placebo gel, topical analgesic gel, rolling and placebo gel, and rolling and topical analgesic gel. All sessions involved 2 ROM and PPT pretests separated by 5 min. Further, after a 20-min recovery period, 2 posttests of ROM, PPT, and heel raises to failure (HRF) were completed at 5-min intervals. In sessions including gel application, immediately after posttest 2, the gels were manually applied on the dominant-leg calf muscles. In sessions including self-massage, 18 min after pretest 2, a rolling massage protocol of 3 sets of 30 s with 10-s rest for a score of 7/10 on the pain scale to cadence of 1 s for the full length of the muscle was conducted from the same sitting position.
Statistical analysis: A 5 conditions $\times$ 4 times repeated-measures ANOVA () was used to analyze PPT and ROM, whereas a 5 conditions $\times$ 2 times ANOVA was used for HRF.
Results: There were no significant main effects for condition or any interactions. A main effect for time (P = 0.031) showed meaningful but no statistically significant (P = 0.1) increases in PPT with near-significant increases between pretest 1 (35.9 $\pm$ 10.1 kg) and pretest 2 (38.3 $\pm$ 12.6 kg) and significant (P = 0.02) increases from posttest 1 (36.3 $\pm$ 11.4 kg) to posttest 2 (38.9 $\pm$ 12.8 kg). ROM also showed a main effect for time ($P < 0.0001$), with significant improvements between all times and with the exception of results from posttest 1 to posttest 2 [pretest 1 (13.8 $\pm$ 3.1 cm), pretest 2 (14.08 $\pm$ 3.2 cm), posttest 1 (14.28 $\pm$ 2.9 cm), posttest 2 (14.4 $\pm$ 3.3 cm)]. HRF showed a main effect for time, with a significant (P = 0.006) decrease in repetitions from posttest 1 (22.1 $\pm$ 6.7) to posttest 2 (20.4 $\pm$ 4.4).

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Conclusions: In contrast to prior rolling studies, there was no augmentation of ROM or PPT and there was no isolated or additive effect with the use of topical analgesic. This lack of significance might be attributed to the inclusion of 2 pretests, a nonclinical healthy young population (no pain or injuries), a more restricted ROM associated with the ankle joint, or type II errors (false negatives with a relatively small sample population).
Clinical applications: The use of roller massagers and topical analgesic alone or in combination may have limited effects in the ankle joint model of a healthy population, and further research should investigate clinical populations and other joint/muscle complexes/regions.

Keywords: Biofreeze; placebo; range of motion; roller massage

Key Point: The use of a topical analgesic alone, a roller massage alone, or a combination of both were ineffective for increasing ankle dorsiflexion range of motion, pressure pain threshold, or heel raise endurance task.

INTRODUCTION

Foam rolling and roller massagers are relatively recent and popular devices used to increase range of motion (ROM) or flexibility (see reviews[1,2]) and decrease pain sensitivity,[2] and in some reports, improve performance.[1] The use of rolling has led to significant improvements with hip flexion (hamstrings),[3–8] hip extension (quadriceps),[3,9,10] knee extension (quadriceps),[5,11–13] ankle dorsiflexion (plantar flexors),[14–16] and sit-and-reach ROM.[17] However, the results in the literature are not unanimous, as some studies have reported trivial effects of rolling on the following ROMs: knee extension[18] and flexion,[19] ankle dorsiflexion,[20] and sit-and-reach performance[21]. Although statistically significant, a 60-s bout of quadriceps rolling can induce a small change in hip flexor and quadriceps flexibility, which was of little practical relevance.[22] Vigotsky et al.[23] observed a small change in hip extension with the use of foam rolling; but, there were no improvements in knee flexion or rectus femoris length. A review of 4 applicable studies by DeBruyne et al.[24] indicated that there was limited evidence for the effectiveness of foam rolling to increase hamstring flexibility in asymptomatic physically active adults. Hence there is some conflict in the literature regarding the effectiveness of rolling for improved ROM.

One of the mechanisms proposed to increase ROM with stretching and rolling is an increase in stretch tolerance.[25,26] An augmented stretch tolerance would suggest that the individual can withstand or accommodate greater stretch or rolling-induced discomfort or pain and thus push themselves to achieve greater tissue elongation and joint ROM. Killen et al.[27] reported improvements in contralateral hip flexion following unilateral rolling and attributed the nonlocal flexibility improvement to an increase in stretch tolerance. Similar mechanisms have been suggested with improved sit-and-reach flexibility after performing rolling for the sole of the foot and increased contralateral ankle dorsiflexion ROM.[16] Thus, any endogenous (i.e. opiods such as endorphins or enkephalins) or exogenous mechanisms, techniques, or applications that could increase pain tolerance (decrease pain) may ameliorate joint flexibility. The application of foam rollers and roller massagers has led to decreases in delayed-onset muscle soreness[28] and increases in pain pressure threshold (PPT) (decreased pain sensitivity).[29–34] However, Fleckenstein et al.[35] reported no clinically meaningful change in pain sensitivity following 30 s of performing foam rolling of the lower limbs.

Topically applied gels, which contain menthol, used as analgesics, can act as a counterirritant to reduce pain sensation.[36–38] The analgesic effect is proposed to work by exerting an inhibitory gate control over nociceptive inputs.[39] No studies have investigated whether the use of topical analgesics alone or in conjunction with rolling would increase ROM, theoretically, by strengthening the stretch tolerance mechanism. It is possible that exogenous application of a topical analgesic that could increase pain tolerance of the affected limb could contribute to greater increases in ROM.

Fatiguing or exhaustive physical activities can be uncomfortable or painful. Increased pain tolerance could permit an individual to persist longer with this type of uncomfortable or painful task. Fleckenstein et al.[35] found that the use of a foam roller improved recovery after an exhaustive agility protocol. Postexercise fatigue from a series of athletic tests (i.e. vertical jump, squats, agility) reduced after the performing foam rolling.[40] With there being few studies that assessed the effects of using rollers for fatigue, it is not known whether the combination of rolling and topical analgesic would have an additive effect on pain tolerance to improve endurance associated with a fatiguing task. Furthermore, it is important to be cautious, as excessive prolongation of a fatiguing or painful activity might lead to acute or chronic injuries.

Therefore, the objective of the present study was to investigate the effects of roller massage and a topical analgesic alone and a combination of both on PPT,

ROM, and performance in a fatiguing exercise. It was hypothesized that the addition of a topical analgesic would increase local pain tolerance and improve ROM, PPT, and the duration of the fatiguing heel raise to failure (HRF) exercise.

METHODS

Participants

Sixteen healthy, active male participants (age range, 18–27 years, 22.3 ± 4.6 years; height, 178.4 ± 6.2 cm; weight, 83.1 ± 10.1 kg) free of musculoskeletal injuries were recruited using convenience sampling by word of mouth. All participants completed all 5 conditions in a randomized order, at least 48 h apart. A minimum of 48 h was allocated between sessions, as the pilot study showed that the site where the conditions were applied to assess PPT could become considerably sore and/or sometimes bruised for 2 days following testing. The Interdisciplinary Committee on Ethics in Human Research (20180888-HK) approved of this study, and participants signed a written consent form after being informed of the risks and protocols involved in the study.

Experimental Design

A repeated-measures (crossover) experimental design was conducted using 5 conditions (Figure 1). All tests were performed by the same examiner in the same order to increase reliability and to decrease error associated with interrater testing. A warm-up session consisting of 5 bilateral full-range calf raises in the standing position on a platform (10 cm) with heels suspended was included.

All sessions involved 2 pretests of ROM and PPT separated by 5 min. Prior studies have reported significant increases in ROM and PPT when a second pretest was incorporated.[15,31,41,42] Hence, the second pretest was used to minimize changes associated with the testing protocol. Following the second pretest, a placebo gel or a topical analgesic gel was applied or no gel was applied, and the participants were instructed to rest for 20 min. The use of placebo or a topical analgesic (Biofreeze, Performance Health Inc., Akron Ohio) was blinded to all researchers and participants. Prior research has reported that this topical analgesic (Biofreeze) take ~20 min to reach full potency (Performance Health recommendations[43,44]). For the 2 combination conditions (topical analgesic gel and rolling and placebo gel and rolling), there was an 18-min rest period rather than 20 min, as the massage protocol took ~2 min to complete. The rolling massage protocol consisted of 3 repetitions of 30-s rolling with 10-se rest between repetitions at a cadence of 1 s for the full muscle length. Rolling intensity was established at a score of 7/10 on the pain scale as indicated by the participant.[15,17,41] This rolling protocol has previously been effective for increasing dorsiflexion ROM.[15] Rolling was conducted in the sitting position, similar to the position used for the PPT testing. Posttest measures of ROM, PPT, and HRF test were conducted immediately postintervention and 5 min thereafter.

Topical Analgesic and Placebo Applications

Depending on the trial, a topical analgesic gel (Biofreeze) or a placebo gel was applied. Thirty grams of the gel (Biofreeze or placebo) was given to the participant, and they were instructed to apply the gel over the posterior part of the lower leg for 30 s. Participants were then instructed to rest for 18 (rolling sessions) to 20 (no rolling sessions) min. Prior research has reported that this topical analgesic (Biofreeze) takes ~20 min to reach full potency.[43,44]

Roller Massage Protocol

Subjects were informed about the details of the protocol and instructions for appropriate use of the roller massager provided (TheraBand®, Performance Health Inc.) before rolling the triceps surae. Rolling massage was performed 18 min after gel application. In the same position as that used for PPT testing, participants self-massaged the back of the calf of the dominant leg by using a roller massager. The participant was instructed to apply strokes at 1 Hz in accordance with a metronome (1 s up, 1 s down) to the medial, posterior, and lateral aspects of the calf, rotating through the 3 areas. Rolling consisted of 3 sets of 30 s with 10 s of rest. Participants were instructed to apply the roller at an intensity that evoked pain registering a score of 7/10 on the pain scale.[15,17,41]

ROM Testing: Weight-Bearing Lunge Test

To determine participants' dominant leg, they were asked to kick a soccer ball. The dominant leg was then positioned 10 cm from a wall that was marked with

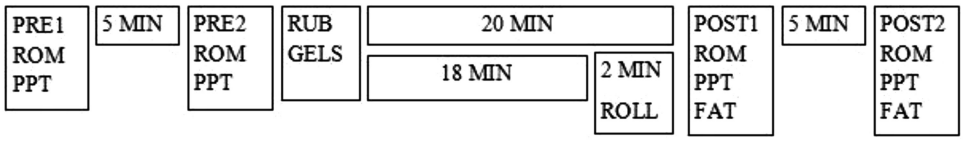

Figure 1. Experimental design.

tape. A card was placed on the tip of the big toe to ensure distance was maintained. With hips parallel to the wall, participants were instructed to flex the knee in an attempt to bring their knee closer to the wall in a controlled manner. A flat rubber band was placed under the heel, with slight tension applied horizontally by the researcher. If the participant's heel lifted and the band was released from the heel while attempting to touch the wall with the knee, it was registered as an incomplete repetition. The participant was allocated a 15-s rest period while their foot was moved either closer to (band released from heel on prior trial) of farther from (band remained in position) the wall followed by another attempt to touch the wall with the knee without lifting the heel. If the knee touched the wall, it was registered as a successful attempt. The researcher determined the maximal distance the participant could reach in a minimum number of trials using 0.5- to 1-cm increments. The in-line weight-bearing ankle ROM test has been used previously[15] and was found to have high interrater and intrarater reliability.[45]

PPT Testing

Participants were seated in a chair with their dominant hip and knee flexed at 90° and the heel elevated at 10 cm on an aerobic step. The lower leg was measured from the medial malleolus to the tibial plateau. A mark was made at a proximal position; two-third up the leg toward the knee, approximately in the middle of the medial gastrocnemius muscle belly. The computer monitor was turned away from the participant, so they could not watch the force applied (thus reducing participant reactivity or anticipation). Participants were given a hand-held clicker and instructed to "press the button when the sensation transitioned from a feeling of pressure to pain. The same verbal instructions were given to every participant in every session. The researcher pressed the tip of the algometer (1.3 cm^2 or 0.5 in^2) into the mid-belly of the medial gastrocnemius at a constant rate of 5 N/s, following a running linear slope on the Tracker program (Tracker 5 JTECH-medical software, Midvale, UT). The researcher used the other hand to brace the front of the shin to minimize movement.

Heel Raise Test (endurance exercise test)

Following ROM and PPT testing in posttests 1 and 2, an HRF was performed unilaterally on the dominant leg while standing on an aerobic step (10 cm). The participant positioned their foot comfortably so that the heel and arch was suspended over the edge of the step. The participant positioned their fists to the wall to assist with balance, but not assist in the movement. The participant was instructed to dorsiflex as far as comfortable by lowering their heel and keeping their leg straight. A light elastic band was positioned at the lowest point the participant could attain (greatest dorsiflexion ROM) with a small visible bend indicating full descent. For the ascent segment of the movement, participants also needed to bring their heel up parallel to the step to successfully complete a repetition. These 2 markers (ascent and descent) were monitored by the researcher to determine task failure. To a 1-Hz metronome cadence (1 s up, 1 s down), the participants would perform heel raise as high as possible before returning to the bottom (elastic band depth). This task was done until failure defined as the inability to perform heel raise past parallel or keep pace with the metronome. The number of "heels up" were recorded as repetitions.

Statistical Analysis

Statistical analyses were computed using IBM SPSS Statistics software (IBM Corp, IBM SPSS Statistics for Macintosh, Version 23.0. Armonk, NY). Dependent variables underwent assumption of normality (Shapiro–Wilk test) and sphericity (Mauchley test), and if violated, the corrected value for nonsphericity with Greenhouse–Geisser epsilon was reported. Initially, a 5 conditions × 4 times within-subject, repeated-measures ANOVA was used to analyze the ROM and PPT. With 16 participants, it was feared that a type II error problem could occur with a 5 × 4 repeated analysis. Because a testing effect was evident with the significant increase from pretest 1 to pretest 2 and there was both a sham and a control condition, the data were analyzed a second time with a 4 conditions (sham used as the control) × 3 times (pretest 2, posttest 1 and posttest 2) repeated-measures ANOVA to decrease the variability and hopefully decrease the possibility of type II errors (false negatives). A 5 conditions × 2 times within-subjects, repeated-measures ANOVA was used to analyze heel raise endurance test. If a significant effect was found, a Bonferroni correction post hoc analysis was performed to determine where the differences occurred. Effect sizes as calculated with eta-square are reported for the significant main effects. Individual effect size comparing specific times were calculated as ((mean 1 − mean 2)/mean standard deviation (SD) of mean 1 and mean 2) (Table 1). Effect sizes are used to provide a magnitude of change descriptors and have been reported as trivial (<0.2), small (0.2–0.49), medium (0.5–0.79), or large (≥0.8).[46]

RESULTS

PPT

Both repeated-measures ANOVA tests (5 × 4 and 4 × 3) exhibited significant PPT main effects for time (P = 0.031, eta^2 = 0.36 and P = 0.04, eta^2: 0.20,

Table 1. Main effects for time

	PPT (kg)	ROM (degrees)	HRF (repetitions)
Pretest 1	35.93 ± 10.1	13.83 ± 3.1	
Pretest 2 (5 min later)	38.33 ± 12.3 6.6%↑ ES = 0.21	14.08 ± 3.0 1.8%↑ ES = 0.08	
Posttest 1 (immediate postintervention)	36.33 ± 11.4 5.2%↓ ES = 0.16	14.28 ± 3.1 1.4%↑ ES = 0.06	22.07 ± 6.76
Posttest 2 (5 min after Posttest 1)	38.98 ± 12.9 7.2%↑ ES = 0.21	14.41 ± 3.1 0.9%↑ ES = 0.04	20.43 ± 5.61 7.4%↓ ES = 0.26

Legend: Means ± SD. Percentage change and effect sizes (ESs) from the prior testing period (i.e. pretest 2 to pretest 1, posttest 1 to pretest 2, posttest 2 to posttest 1) are also reported.

respectively). The 5 × 4 analysis showed a 6.6% PPT increase from pretest 1 to pretest 2 (P = 0.0001), as well as a 7.2% increase from posttest 1 to posttest 2 (P = 0.02). The 4 × 3 analysis showed a significant increase from posttest 1 to posttest 2 (P = 0.01) (Table 1). There were no significant main effects for conditions or interactions with either analysis.

ROM

Both repeated-measures ANOVA tests (5 × 4 and 4 × 3) exhibited significant ROM main effects for time (P = 0.0001, eta^2 = 0.65 and P = 0.001, eta^2 = 0.36, respectively). The 5 × 4 analysis showed that all times were significantly different, with the exception of lack of significant difference from posttest 1 to posttest 2 ROM (Table 1). The 4 × 3 analysis showed a significant 1.9% increase from pretest 2 to posttest 2 (P = 0.008). There were no significant main effects for conditions or interactions with either analysis.

HRF Test

Significant main effects for time (P = 0.006, eta^2 = 0.41 and P = 0.027, eta^2 = 0.28, respectively) were observed. The posttest 2 showed a 7.4% decrease from posttest 1 to posttest 2 (Table 1).

DISCUSSION

The most important findings in the present study were the lack of a significant and meaningful effect of a topical analgesic (Biofreeze) and rolling massage, alone and in combination, on PPT, ROM, or HRF endurance tests. This is the first study, to the best of our knowledge, to investigate the possibility that a topical analgesic would conceivably increase the stretch tolerance level and promote a greater increase in ROM.

The lack of significant increase in ankle dorsiflexion ROM is in accord with the results of Skarabot et al.'s study.[20] Similar to the present study, Skarabot et al.[20] also incorporated 3 × 30 s of rolling. However, they recruited 11 adolescent athletes, with foam rolling rather than roller massage. The present results contradict 2 other acute studies that report increased ankle dorsiflexion ROM with rolling.[15,16] Similar to the present study and Skarabot's study, Halperin et al.[15] (roller massage), and Kelly and Beardsley[16] (foam roller) had 14 and 26 recreationally active university students perform rolling for 3 × 30 s and found 5.4% and 8.8% increases, respectively. These discrepancies likely stem from the low statistical power involved in the current and cited studies. A meta-analysis will increase statistical power and thus allow for a more accurate investigation as to the size of the effect, if at all present. Another possible reason for the discrepancy is the limited ankle ROM. Using the ankle joint as a research model has inherent challenges owing to not only the soft tissue/connective tissue restraints but also the anatomical/physiological barriers of the skeletal structures (e.g. talar approximation with the tibia, talocalcaneal joint).

Despite that the in-line lunge test is reliable, which was one of the main reasons why it was selected for this study, the extent of ankle dorsiflexion is relatively small compared with the extent of movement of joints with far greater flexibility. For example, ROM of ankle dorsiflexion can range from 15°–22°, whereas ROM of other joints such as hip flexion (100°–128°), knee flexion (135°–150°), or shoulder flexion (150°–180°) may be 5- to 9-fold greater.[47] Thus, achieving a substantial change in ankle dorsiflexion ROM is far more difficult than achieving that with many other joints.

As mentioned in the statistical analysis, we attempted to reduce the variability and increase statistical power by performing 3 sets of ANOVA tests. It could be argued that as there was a sham condition, there was no need for the other control condition. Furthermore, it has been shown that there is a repeated testing effect and thus the second ANOVA test did not

include the first pretest. However, both ANOVA tests (5×4 and 4×3) provided similar results. Hence within the limitations of the present study, the improved ROM was attributed to a repeated testing effect.

Likewise, there was a PPT main effect for time but no main effect for conditions or interactions. Prior publications have shown an increase in PPT with self-massage using foam rollers and roller massagers.[29–34] However, Fleckenstein et al.[35] reported no clinically meaningful change in pain sensitivity following 30 s of foam rolling of the lower limbs. A number of the studies that show increased PPT have used rolling to reduce muscle tender points,[31] or have induced acute pain[33] (evoked tetanus,[34] delayed-onset muscle soreness) or tested the iliotibial band[32] rather than a more compliant muscle group. Healthy male participants with no apparent prior pain and free of musculoskeletal injuries were included in the present study. The test for PPT was the identification of the initial detection of pain or discomfort from the pressure of the algometer. Perhaps the topical analgesic and roller did not provide sufficient analgesic effects to detect changes in the initial pain pressure but might have detected differences if the threshold had been a greater degree of pain or the participants had been a clinical population with higher inherent pain sensitivity. Similarly, the discomfort associated with performing repeated heel raises may not have been severe enough to induce any positive pain tolerance endurance benefits.

A potential limitation of the study would be to question whether the PPT findings could have differed if applied to the medial gastrocnemius or other muscle groups, if the gastrocnemius was lengthened vs. shortened, thus being affected by muscle length/tension.

CONCLUSION

The use of a topical analgesic alone, a roller massage alone, or a combination of both were ineffective for increasing ankle dorsiflexion ROM, PPT, or heel raise endurance task. The 2 conditions did not augment the proposed stretch or pain tolerance to improve ROM or endurance. Future studies should examine joints with a greater ROM using substantially greater number of participants and particularly clinical populations with greater pain sensitivity.

Conflict of Interest: The authors declare no conflict of interest with the information provided within the manuscript.

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