The effects of one session of roller massage on recovery from exercise-induced muscle damage: A randomized controlled trial

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ABSTRACT

Background/objective: Roller massage has become a popular intervention in sports settings in order to treat muscle soreness and stiffness, as well as improving post-exercise recovery, although there is limited evidence for these assumptions. Therefore, the purpose of this study was to evaluate the effects of a single session of roller massage, applied with a controlled force after an exercise-induced muscle damage protocol, on muscle recovery.
Methods: A randomized controlled study was performed using a repeated-measures design. Thirty-six young men completed four sets of six eccentric actions of elbow flexors at $90°/s$ with a 90s rest interval between sets. Participants were randomly assigned into one of three groups: 1) Roller massage (n = 12), 2) Sham (n = 12), and 3) Control (n = 12). Maximal isometric voluntary contraction (MIVC), delayed-onset muscle soreness (DOMS), range of motion (ROM), and muscle thickness were measured at baseline, and at 24, 48, and 72 h post exercise.
Results: There was no significant group by time interaction for MIVC (p = 0.090) and ROM (p = 0.416). Also, although there was a significant group by time interaction for muscle thickness (p = 0.028), post hoc test did not find significant difference between groups (p > 0.05). DOMS was recovered at 72 h for roller massage (p < 0.001) and control (p < 0.001) groups, while the Sham group did not recover from DOMS across 72 h (p < 0.001). There was also no significant difference between groups in DOMS at any time (p > 0.05).
Conclusions: A single session of roller massage applied on elbow flexors had no effect on recovery of MIVC, muscle swelling, ROM and DOMS.

Introduction

Eccentric actions impose high mechanical stress on the muscular structure that can trigger a sequence of physiological and morphological events, leading to a decrease in muscle strength, delayed onset muscle soreness (DOMS), muscle swelling and an increase in the concentration of inflammatory biomarkers in the bloodstream.[1,2] This condition is traditionally used to characterize muscle damage induced by exercise. Muscle damage is a potentially contributing stimulus for the occurrence of chronic adaptations associated with physical exercise. However, when excessive, it can impair the performance and ability to perform subsequent physical training. Several strategies have been used to prevent, minimize or even accelerate the recovery of symptoms generated by exercise-induced muscle damage (EIMD); among them, massage.

Massage is a broad term under which specific approaches or techniques are classified.[3] Most massage techniques are applied exclusively by a qualified professional. The use of massage devices, including foam roller, ball, roller massage and many other tools, is an approach that has become popular in sport and clinical settings, due to the possibility of them being used by a technician or by the

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individual themselves.[4,5] The foam roller and roller massage are performed after exercise-induced muscle damage in order to manage the signs and symptoms of muscle injuries.[6,7] However, there is no consensus regarding the optimal weekly frequency, pressure on the underlying tissue, or the ideal moment in which the intervention should be performed.

Of the studies that evaluated the effects of massage with a foam roller or roller massage after muscle damage, only two[8,9] measured the magnitude of force applied during the intervention, both in relation to body weight of the participants. MacDonald et al.[8] measured the force placed on the foam roller using a force plate, while Casanova et al.[9] used a roller massage machine with a constant pressure rolling device. In sports settings, the force applied is usually determined by the level of discomfort presented by the participant.

In addition, it has been reported that roller massage or foam roller performed post-exercise and after each testing point (24, 48, and 72 h) after EIMD attenuates decrements in lower extremity muscle performance,[8,10] improved range of motion (ROM),[8] pain tolerance,[9,10] and reduced muscle soreness.[8] When performed post-exercise and before each test point post EIMD, foam roller conditioning improved jump performance and pain tolerance compared to the control group. At 48 h post EIMD, the intervention improved ROM and pain tolerance, and reduced muscle soreness.[11] On the other hand, when foam roller or roller massage was performed 48 h post EIMD, or each day after warm up, no effect was observed in ROM,[12,13] muscle soreness,[12,13] or maximal isometric voluntary contraction (MIVC).[12]

The contradictory findings may be due to differences in the procedures or experimental design of the studies. Therefore, it is very important to examine how a single session of roller massage, performed after muscle damaging exercise, can influence indirect muscle damage markers throughout a 72 h period. Previous studies examined the effects of mechanical pressure applied with a foam roller or roller massage on subsequent days, before or after EIMD. Furthermore, few studies have objectively controlled the magnitude of force applied during massage.

Thus, the purpose of this study was to evaluate the effects of a single session of roller massage, applied with a controlled force after an EIMD protocol, on muscle recovery. To our knowledge, this is the first study to objectively control the magnitude of force applied during roller massage, and to observe the short-term and middle-term (24, 48, and 72 h) effects of roller massage on changes in indirect markers of EIMD on elbow flexors. On the basis of the previous studies, we hypothesized a reduction in the extension of muscle damage signs and symptoms by the use of roller massage.

Methods

Participants

The total sample size was determined considering data of a pilot study. It was used the G*Power (version 3.1.2; Frans Faul, University of Kiel, Germany), with the level of significance set at $\alpha = 0.05$, power $(1-\beta) = 0.80$ and effect size $f = 0.25$, and a statistical two-way ANOVA test with repeated measures, within and between interaction. The sample size estimated according to these specifications was 12 participants in each group. Forty-seven volunteers were assessed for eligibility; four did not meet the inclusion criteria, two declined to participate after the familiarization session and five participants declined for diverse reasons. Therefore, 36 healthy males from the University campus (21.1 ± 2.1 years, 174.7 ± 4.9 cm, and 68.1 ± 10.7 kg), classified as physically active in accordance with *International Physical Activity Questionnaire* (IPAQ), were recruited via a convenience sample. Inclusion factors for participants included (i) age between 18 and 25 years, (ii) no

experience with roller massage, (iii) and had not been engaged in resistance exercise programs over the past six months. Participants exclusion criteria included taking medications or supplements, musculoskeletal disorder, and neurosensory or metabolic conditions that would affect variables test. The participants who fulfilled the inclusion criteria were verbally informed of all experimental procedures and, if willing to participate, read and signed a written consent form approved by the institutional Research Review Board (Approval#: CAAE 48507815.9.0000.0030) with a clinical trial register RBR-3h6q4c. All participants were asked not to perform unaccustomed or heavy exercise during the experimental period and to avoid the consumption of alcohol, caffeine, or other stimulating substances.

Study design and procedures

A randomized controlled study was performed using a repeated-measures design to examine the effects of roller massage on elbow flexors after four sets of six eccentric elbow flexor contractions protocol with 90 s of rest between each set. Participants attended the laboratory on five occasions, each visit lasting an average of 40 min. The first visit consisted of a familiarization session, to introduce the study procedures, anthropometric measurements and the determination of the mechanical pressure to be applied. Seven days later, on the second visit, all participants performed an EIMD protocol. Five minutes after, the participants were randomly assigned to one of three different groups: 1) Roller massage (n = 12), 2) Sham (n = 12), and 3) Control (n = 12). The third, fourth and fifth visits corresponded to the 24 h, 48 h and 72 h post EIMD protocol. Considering that it was not possible conducted a double-blind experimental design, the Sham intervention was used to evaluate the effects of possible influence of psychological factors[14] and the control group was used for accounting the random error.

A professional, who was not involved with the study, sealed the envelopes using the method of sequentially numbered, opaque sealed envelopes.[15] The researcher who recorded all tests was blinded to the intervention administered as well as the outcome assessor. One single evaluator, who was blinded to the group assignments, performed all tests and the participants were instructed not to reveal to which condition they were exposed.

The primary variable, MIVC of the elbow flexors, and the secondary variables, DOMS, ROM and muscle thickness of the elbow flexors were measured before (pre), and 5 min, 24 h, 48 h and 72 h post the damaging exercise, with assessments always carried out in the same order. All measurements were performed on the dominant arm always in this order. A flow chart of the study design is presented in Fig. 1.

Exercise-induced muscle damage protocol

The participants performed the EIMD protocol with the elbow flexors using an isokinetic dynamometer Biodex System 3 (Biodex Medical, Inc., Shirley, NY, USA). The EIMD protocol consisted of four sets of six repetitions of maximal eccentric contraction of elbow flexors of the dominant arm at 90°/s, with 90s of rest between sets. The eccentric contractions were executed from a 60° to a 170° elbow angle (180° = full extension). Between each contraction, the arm was passively repositioned at 60°. The laboratory was kept at room temperature during all test sessions (22 °C).

Experimental treatment

In a pilot study, was observed that roller massage applied with mechanical pressure greater than pain perception of 6—7 prompted
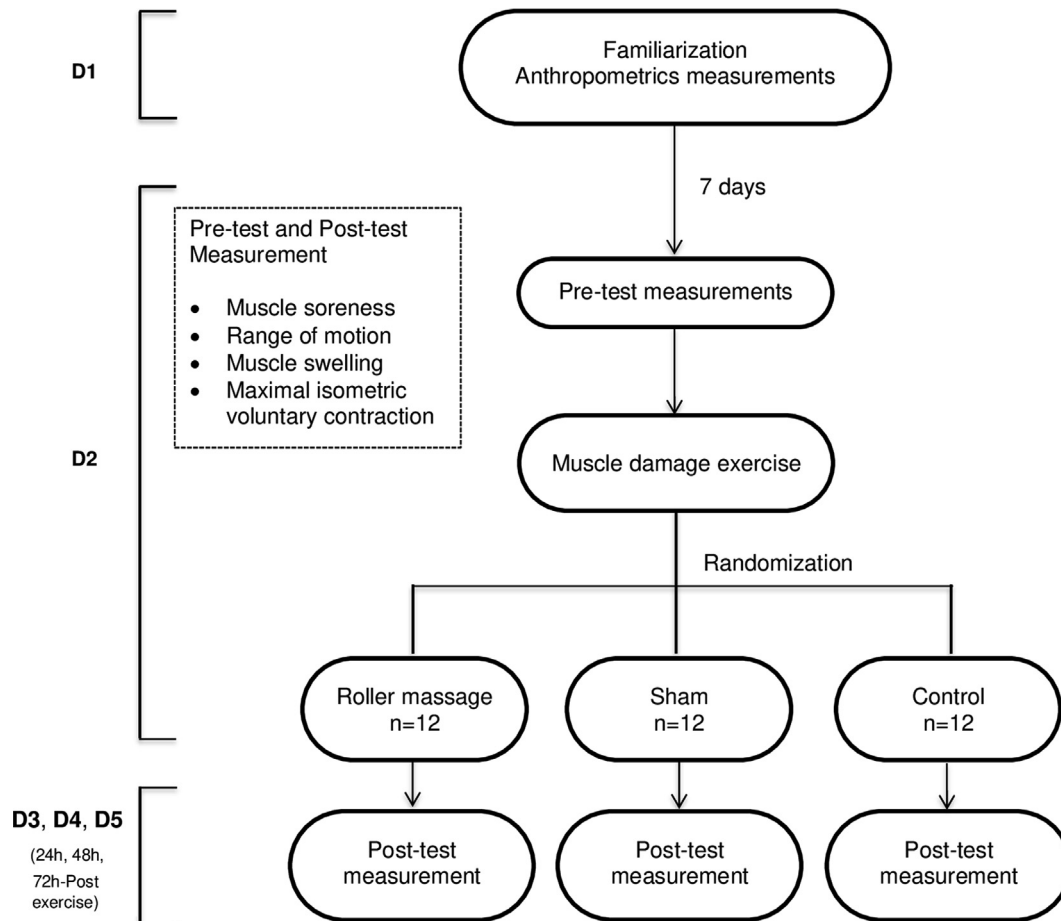
Fig. 1. Flow chart of the study design. D: day.

the participants not to tolerate the duration of 5 min of the roller massage. In other words, the highest pressure tolerated during 5 min of roller massage corresponded to the pain perception of 6–7 on a numerical rating scale. The roller massage was designed to measure the magnitude of the load applied during the intervention. It has strain gauges affixed to the roller rod to transmit the signal via Bluetooth to the computer (Fig. 2). The signal is acquired by a human-machine interface computational tool, allowing the magnitude and pressure control to be visualized on the screen. In order, to put the equipment in conditions of use, before each test session, known loads (2.2, 4.2, 6.2, 8.2 and 11.2 kg) were applied for the calibration of the equipment. The calibration curve was processed using a second-degree polynomial that generated three indices. These were inserted in the human-machine interface, allowing the signal to be represented and collected in kilograms (kg). This way, it was observed that the pain perception of 6–7, on a numerical rating scale, corresponded to the magnitude of force applied of 4–5 kgf.

The participants lay on a massage table in a supine position in order to be exposed to one of the three mentioned conditions. Roller massage was performed with a constant stroking rhythm going from distal to proximal of the elbow flexors, at a frequency of 60 beats per minute for 5 min, controlled by a metronome with magnitude force of 4–5 kgf, corresponding to the pain perception of 6–7 on a numerical rate scale. As there is still no agreement related to treatment parameters for frequency of rolling massage, number of repetitions, cadence of motion, and duration of intervention,[16] we applied an intervention duration that can be applicable in a clinical and sports environment.

Fig. 2. Roller massage device used. This device was 18 cm in length and 3 cm in diameter with a dense rubberized surface, and it had strain gauges affixed to the roller rod to transmit the signal via Bluetooth to a computer, allowing to control the magnitude of force applied during the intervention.

The roller massage used (Tiger tail, USA) was 18 cm in length and 3 cm in diameter with a dense rubberized surface (Fig. 2). Strain gages were attached to its inner rod to control the magnitude of force applied during the intervention. The signal was amplified

and filtered, allowing a signal frequently below 7 Hz. This signal was transmitted to a computer that had a Human-Machine interface, allowing control of the force applied. The sham massage was applied for 5 min using an ultrasound probe, which was off. The ultrasound transducer was moved smoothly, taking care not to compress the tissue, using an identical procedure to the roller massage. Participants of the control group were kept at rest for 5 min.

Delayed-onset muscle soreness

DOMS was assessed during palpation of the biceps brachii muscle venter. The participants were instructed to verbally express the magnitude of perceived pain, using a numerical scale ranging from 0 to 10, where "0" is perceived as the "total absence of pain" and "10" as the maximum tolerable pain. The intraclass correlation coefficient (ICC) value for biceps brachii DOMS was 0.86.

Range of motion

ROM was measured by photogrammetry. Two photographic images were recorded with a machine (Samsung Camera S860 8,1mp); the participant had the elbow relaxed in extension in the first image and in maximum flexion in the second image. The ROM was calculated by a specific algorithm developed in MatLab 6.5, which specified the difference between the angle with the elbow relaxed and in maximum flexion. To perform ROM calculation, anatomical reference points were marked in the deltoid insertion, lateral epicondyle of the humerus, and the midpoint between the ulnar and radial styloid processes. These points were marked with high fixation paint to ensure that they would remain throughout the study period. The test-retest ICC value for ROM at the start of each trial was 0.88.

Muscle thickness

Muscle swelling was expressed as muscle thickness and was measured by Ultrasonography using B-Mode ultrasound (Philips-VMI, Indústria e Comércio Ltda. Lagoa Santa, MG, Brazil). A water-soluble transmission gel was applied to the measurement site, and a 7.5-MHz ultrasound probe was placed parallel to the muscle force direction and perpendicular to the muscle examined. Muscle thickness of the elbow flexors was taken as the distance from the subcutaneous adipose tissue-muscle interface to the muscle-bone interface. For the measurement of muscle thickness, JPEG images were analyzed in the software Image-J (National Institute of Healthy, USA, version 1.47). Three different measurements were performed, and the mean value was used for analysis. ICC between baseline muscle thickness at the start of each trial was 0.85.

Maximal isometric voluntary contraction

Maximal isometric voluntary contraction of the elbow flexors was evaluated with the volunteer seated on a chair with a specific arm rest. The elbow was positioned at $90°$ ($0°$ full extension) by using an analog goniometer (TTK, model 1216). A load cell (AEPH do Brasil Indústria e Comércio Ltda., TS model, 100 kg ± 10%) was attached to the chair with a grab handle fixed at its end by an inextensible iron chain. This handhold was adjusted so that the participant maintained $90°$ of elbow flexion.

The participants were instructed to maximally contract the elbow flexors for 4s. They performed two attempts, with 90s of rest between them. The signal was filtered, allowing the passage of the low frequencies, with a cutoff frequency of 2 Hz. An algorithm developed in MatLab 6.5 (Mathworks; Natick, MA, USA) was used

to analyze the MIVC and the greatest value between the two attempts was recorded. The test-retest ICC value for maximum isometric strength of the elbow flexors was 0.97.

Statistical analysis

All data were analyzed in the Statistical Package for the Social Sciences (version 20.0; SPSS Inc., Chicago, IL, USA). The physical characteristics were evaluated using a one-way (group) ANOVA. A two-way (group x time) repeated measures ANOVA was used to analyze ROM, muscle thickness and MIVC. In the case of significant differences, a Holm-Sidak *post hoc* test was used. Kruskal Wallis (among groups) and Friedman (within group) tests were used to analyze muscle soreness. Significance level was set a-priori at $p < 0.05$. All data are expressed as mean ± standard deviation. Additionally, partial eta squared was calculated by dividing the sum square for the interaction effect by the sum square of that effect plus the error sum square, and was used in G*Power (version 3.1.2; Frans Faul, University of Kiel, Germany) to determine the Cohen's f effect size. Then, Cohen's f effect size was converted to Cohen's d effect size by the equation[17] $d = f$ x 2. According to Cohen,[18] the d values were classified as "trivial" ($d < 0.2$), "small" ($0.2 \leq d < 0.5$)", "medium" ($0.5 \leq d < 0.8$), and "large" ($d \geq 0.8$).

Results

This study started in January 2019 and finished in May 2019. At the beginning of the recruitment period a pilot study was conducted beforehand to determine the mailing parameters for use during the reminder of recruitment. The recruitment packets for the pilot study were mailed two weeks apart in April and May 2018. The quest for participants who met the eligibility criteria for participation in the research started one week after the pilot study realization.

All 36 participants recruited completed the study protocol and full data were obtained for each of them, according to the randomization There was no significant difference ($p > 0.05$) in age, height, weight (Table 1), MIVC, elbow flexors muscle thickness, and ROM between groups at baseline (Table 2).

There was no significant group by time interaction for MIVC (F = 1.893, $p = 0.090$) and ROM (F = 1.032, $p = 0.416$). There was also no significant group effect (F = 0.070, $p = 0.93$; F = 1.831, $p = 0.176$). After 72 h and 48 h each group did not recover MIVC (F = 69.585, $p < 0.001$) and ROM (F = 7.589, $p < 0.001$) to baseline values, respectively (Table 2).

There was a significant group by time interaction for muscle thickness (F = 2.239, $p = 0.028$). Muscle thickness was not altered in the roller massage and control groups throughout 72 h ($p > 0.05$). Although the Sham group did not increase significantly muscle thickness immediately post exercise ($p = 0.074$), muscle thickness reduced from immediately post exercise to 48 h post the damaging exercise ($p = 0.038$). There was also no significant group effect (F = 0.826, $p = 0.015$) for muscle thickness. Also, although there was a significant time effect (F = 3.213, $p = 0.015$) for muscle thickness, post hoc test did not showed significant difference between means ($p > 0.05$) (Table 2).

DOMS was recovered at 72 h for roller massage ($\chi^2 = 33.6$, $p < 0.001$) and control ($\chi^2 = 29.9$, $p < 0.001$) groups (Fig. 3A e 4B, respectively), while the Sham group did not recover from DOMS across 72 h ($\chi^2 = 38.1$, $p < 0.001$) (Fig. 3C). There was also no significant difference between groups in DOMS at any time ($p > 0.05$). Finally, the effect size for all variables was medium (d values ranging from 0.50 to 0.74, Table 2).

Table 1
Physical characteristics of the participants of each experimental group.

	Roller massage group (n = 12)	Sham group (n = 12)	Control group (n = 12)	P-value
Age (yrs.)	20.6 ± 1.6	22.1 ± 2.1	20.6 ± 2.5	0.122
Height (cm)	176.8 ± 6.0	173.1 ± 3.6	174.8 ± 4.6	0.182
Body mass (kg)	73.5 ± 11.9	66.9 ± 7.9	65.1 ± 8.5	0.092

Table 2
Time course recovery of elbow flexors following exercise protocol.

		Pre (baseline)	Post-0h	Post-24 h	Post-48 h	Post-72 h	Time × group interaction p-value	Cohen's d
MIVC (kgf)	Roller massage	19.95 ± 1.69	13.36 ± 2.98	15.80 ± 2.38*	16.77 ± 2.38*	17.80 ± 2.61*	0.090	0.68
	Sham	19.25 ± 3.7	14.52 ± 3.06	15.82 ± 3.46	15.56 ± 3.05*	16.36 ± 3.92*		
	Control	19.34 ± 4.08	14.39 ± 3.26	16.22 ± 3.21	16.12 ± 3.55*	16.76 ± 3.05*		
	All groups	19.87 ± 3.25	17.54 ± 3.06*	15.53 ± 2.97*#¥	16.29 ± 2.98*#¥	17.71 ± 3.20*#		
Muscle thickness (mm)	Roller massage	37.84 ± 5.09	37.14 ± 4.13	37.49 ± 4.96	37.60 ± 5.46	36.83 ± 5.54	0.028	0.74
	Sham	37.40 ± 4.65	39.78 ± 3.15	38.81 ± 3.64	37.11 ± 3.27#	37.52 ± 3.15		
	Control	37.42 ± 5.51	39.74 ± 5.18	38.12 ± 5.03	37.97 ± 4.07	38.90 ± 4.80		
	All groups	37.55 ± 4.95	38.89 ± 4.30	38.14 ± 4.49	37.56 ± 4.25	37.75 ± 4.56		
ROM (°)	Roller massage	137.4 ± 9.4	131.4 ± 10.5	133.9 ± 8.2	134.9 ± 8.1	136.6 ± 8.2	0.416	0.50
	Sham	132.8 ± 8.2	126.8 ± 13.3	130.6 ± 12.4	127.3 ± 11.2	127.2 ± 12.9		
	Control	135.0 ± 6.0	127.6 ± 7.8	129.7 ± 9.3	127.8 ± 7.0	127.5 ± 7.9		
	All groups	135.07 ± 8.0	128.59 ± 10.6*	131.39 ± 10.0	129.99 ± 9.4*	130.46 ± 10.6		

Data are presented as mean ± standard deviation. MIVC: Maximal isometric voluntary contraction; ROM: range of motion; (*) p < 0.05, different from baseline; (#) p < 0.05, different from Post-0h; (¥) p < 0.05, different from Post-72 h.
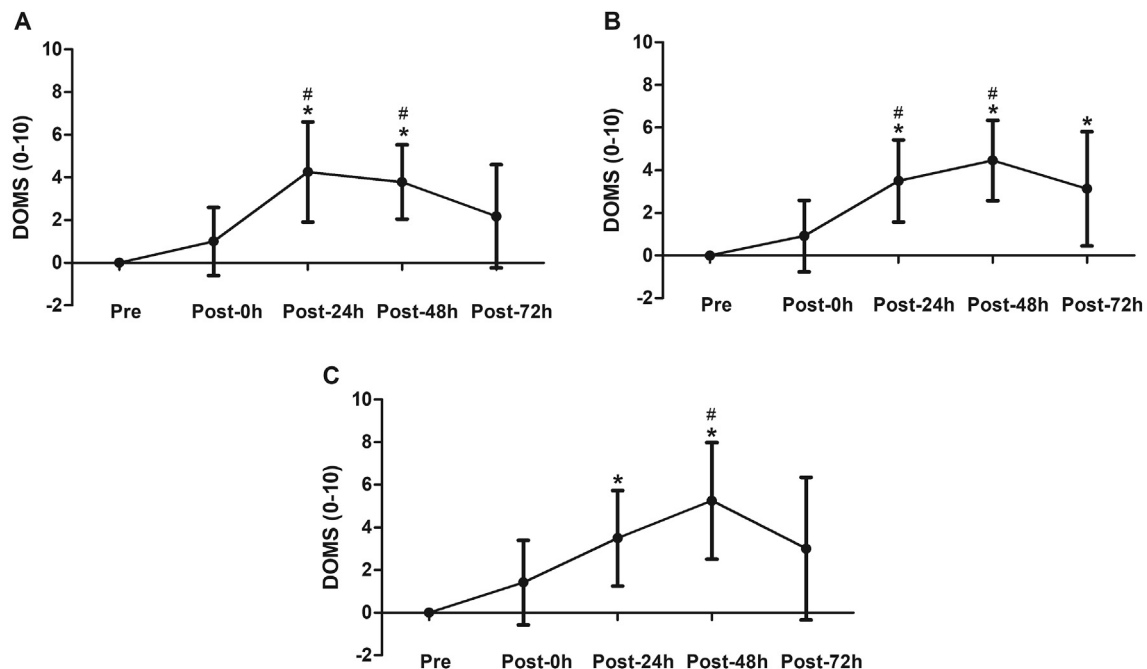

Fig. 3. Delayed onset muscle soreness (DOMS) timeline in the (A) roller massage (n = 12), (B) Sham (n = 12) and (C) Control (n = 12) groups, after elbow flexors exercise-induced muscle damage protocol. (*) p < 0.05, different from baseline; (#) p < 0.05, different from Post-0h.

Discussion and implications

To the best of our knowledge, this is the first randomized controlled trial to investigate the effects of a single session of roller massage using a standardized force on indirect markers throughout 72 h following EIMD in participants with no experience with roller massage. It was hypothesized that a single session of roller massage performed in the elbow flexors for 5 min at a frequency of 60 beats per minute with a force of 4–5 kgf would promote the reduction of signs and symptoms from the damaging exercise. Nevertheless, the results of the current study showed that roller massage did not improve MIVC, ROM, DOMS, and muscle swelling recovery from EIMD.

The damaging exercise performed in the present study promoted impairment in muscle function throughout 72 h post exercise. For example, MIVC did not return to baseline values in any group throughout 72 h. MacDonald at al.[8] also found no significant MIVC recovery after their EIMD protocol. However, Casanova et al.[9]

found a reduced MIVC within 1 h after their EIMD protocol but not after 24 h. It is noteworthy that, in the present study the roller massage was performed only after EIMD, while in the MacDonald at al.[8] and Casanova et al.[9] studies foam roller was applied on three consecutive days. Conversely, Moraleda et al.[19] showed that foam-rolling massage significantly improved MIVC of knee extensors in comparison to neurodynamic mobilization. However, it is important to note that the authors did not evaluate a control or sham treatment, and used a lower limb EIMD protocol, while in the present study we used an upper-limb EIMD protocol.

It is known that the severity of signs and symptoms post exercise is related to muscle damage and that the changes in muscle function reflect the extent of this damage.[1] In the present study, the reduction in force-generating capacity immediately post exercise corresponded to 24—33%, and remained below pre-exercise values over 72 h, which is classified as moderate muscle damage and indicates that some degree of segmental necrosis may have occurred.[1] In the MacDonald at al.[8] study, the reduction in muscle strength was less than 20%, corresponding to mild damage.[1] Mild damage would be linked to low or no morphological indices of damage.[1] It was not possible to evaluate the damage magnitude in other previous studies. It is hypothesized that the roller massage effect on recovery after EIMD may be dependent on the extent of muscle damage. However, this topic requires further investigation.

Surprisingly, ROM remained unchanged over the time of the study and did not differ between conditions. Previous studies found an increase in ROM,[8,10,11] contrasting with our findings. The variation in methodological design, combined with the differences in foam roller or roller massage intervention (e.g., applied load), EIMD protocol, and training status of the populations investigated, has perhaps contributed to the divergent findings. Furthermore, in previous studies the foam roller effect was evaluated in the lower limb, while in the present study the roller massage effect was evaluated in the upper limb. It is known that the magnitude of muscle damage is greater and the recovery of muscle function slower in elbow flexors compared to knee extensors.[20]

In the present study, roller massage was performed only post EIMD while in MacDonald et al.[8] and Pearcey at al.[10] studies it was carried out following exercise across consecutive days (post, 24 h and 48 h post EIMD). Evidence suggests that the application of foam roller on consecutive days may have induced chronic adaptation, leading researchers to speculate that continuing treatment with foam roller may lead to more pronounced effects on muscle contractile properties.[21] In accordance with our findings, D'Amico et al.[13] showed that two sets of 60s of foam roller on lower limbs did not influence hip abduction ROM. Most of the aforementioned studies did not report the extension of muscle damage induced by exercise. Thus, it might explain the difference in the effectiveness of roller massage or foam roller massage after the EIMD protocols used by these authors and the EIMD protocol used in the present study.

It is worth pointing out that muscle swelling is one of the markers of muscle damage[22] and the severity of signs and symptoms post exercise is related to muscle damage.[1] However, post exercise muscle swelling is known to be bi-phasic, since the immediate short-lived swelling is meant to be due to capillary occlusion during exercising (muscle contractions) known as "the pump",[23] and the second increase of muscle volume is meant to be related to the infiltration of fluid, plasma proteins and inflammatory cells.[1,22] The current muscle thickness data indicate that the damage protocol did not induce muscle swelling in the roller massage, sham and control groups. Furthermore, MacDonald et al.[8] showed no substantial between-group difference in thigh girth 24 h, 48 h, and 72 h after a lower-limb EIMD protocol. On the other hand, Casanova et al.[9] found a significant lower muscle thickness

immediately and 24 h after a lower-limb EIMD protocol when compared with a no-roller massage condition. A potential mechanism for the reduced pump is that the external compression of muscle increases the release of vasodilator substances, such as nitric oxide,[24] reducing the concentration of blood plasma in muscle. However, as we and MacDonald et al.[8] did not found evidence indicating muscle swelling after a EIMD protocol, it is hard to known if foam roller and roller massage could improve muscle swelling reduction. Thus, further studies are required to confirm this.

The current findings suggest that the mechanical stimuli performed with the roller did not reduce muscle DOMS. In agreement with our results, D'Amico et al.[13] observed no effect of foam roller on muscle soreness. However, others reported positive effects.[8,10,11] It should be noted that a decrease in muscle soreness perception might be dependent on the pressure applied and the moment of application. Studies that used a mechanical pressure equivalent to 32—55% and 24.2% of body weight observed a reduction in muscle soreness after performing foam roller compression[8,9] while others did not report the pressure applied.[19] In the current study, the pressure was fixed at 4—5 kgf. Additionally, the application of the mechanical stimuli ranged from immediately post, 24 h and 48 h post EIMD in some studies,[8,9] up to a single session performed 48 h following EIMD.[11] Thus, further studies are needed to clarify this issue.

There are some limitations in the present study. Firstly, only indirect parameters of muscle damage were tracked and physically active young males were evaluated. Secondly, due to the nature of the intervention, it was not possible to keep the participants blinded to their group assignment. Thirdly, we could not measure the magnitude of the applied force during the palpation for DOMS assessment; however, a single evaluator performed all tests to avoid great variability between each measurement performed. Additional studies composed of participants with different training levels and carry out the evaluation of the biochemical markers of collagen rupture are needed. Further studies on this topic are also necessary to analyze the optimal level of pressure and application time of roller massage.

Conclusion

This study suggests that a single session of roller massage applied on elbow flexors seems to be a not effective strategy for improvements in signs and symptoms from damaging exercise.

Declaration of competing interest

Medeiros was responsible for overseeing the project including data collection and manuscript preparation. Marinho and Ribeiro contributed with data collection. Ferreira-Junior, Martins and Viana contributed to the statistical analyses and manuscript preparation. Bottaro and Carmo contributed to the study design, discussion of results and manuscript preparation. All authors read and approved the final manuscript.

All authors had full access to all data in the study and take responsibility for the integrity and accuracy of the data analysis and have explicitly agreed to the manuscript being submitted to the Editorial Board. The authors declare no conflict of interest, or financial, or other interest in any product or product distributor.

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Appendix A. Supplementary data

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