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Original Research

Acute Effect of Different Duration of Foam Rolling Protocols on Muscle Thickness, Pain Pressure Threshold, and Volume Load on Multiple Sets of Knee Extension

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ABSTRACT

International Journal of Exercise Science 14(3): 742-755, 2021. Previous studies investigated the effects of foam rolling (FR) on measurements of strength and power. However, the acute effect of FR on muscle thickness (MT) and pressure pain threshold (PPT) after multiple sets of resistance exercise remains to be elucidated. The aim of the present study was to examine the effect of one and three minutes of quadriceps FR on muscle thickness (vastus lateralis [VL] and rectus femoris [RF]), pain threshold (VL and RF), and total load lifted (TLL) on multiple sets of knee extension. Nine resistance-trained men (age: 24.8 ± 5.2 years; height: 177 ± 7 cm; total body mass 77.7 ± 6.2 kg) participated the study. MT, PPT, and performance on multiple sets of knee extension were compared after performing passive recovery (CON), one minute (FR1), or three minutes of FR (FR3). A similar total training load among experimental conditions was observed. There was a greater increase on VL muscle thickness after FR3 when compared to CON and FR1. In addition, there was an increase on rectus femoris PPT two minutes post FR3, with no differences between conditions. These results indicate that longer duration FR-protocol may acutely increase muscle thickness of the vastus lateralis muscle without negatively affect the TLL and PTT.

KEY WORDS: Self-myofascial release, massage, performance, resistance training.

INTRODUCTION

Foam rolling (FR) has become a popular intervention performed prior to resistance training (RT) sessions. FR is a form of self-myofascial release that has shown to increase range of motion without affecting muscle performance (4, 8, 26, 33), possibly by combination of a neural modulation on muscle tone and peripheral alterations of the mechanical tissue properties (5). Additionally, when performed before the main activity, FR has demonstrated to decrease the rate of perceived exertion (19) and the sensation of fatigue (14). Interestingly, previous reports also indicated that FR could increase the pressure pain threshold (3, 8, 19, 31).

FR appears to increase pressure pain threshold (PPT) acutely (indicating an increase on pain tolerance) (3). Jay et al. (19) investigated the effects of ten minutes of massage on the hamstrings using a manual roller massager 24 hours after a delayed onset muscle soreness-inducing protocol. Overall, the massage protocol reduced the soreness and increased PPT on the ipsilateral and contralateral limb. Pearcy et al. (31) observed that a bout of FR for the major thigh muscles caused an increase on quadriceps PPT 24- and 48-h after ten sets of ten repetitions of back squat at 60% of 1RM. Aboodarda et al. (2) also observed an increase on plantar flexor muscles PPT after three sets of 30 seconds heavy manual roller massage. As few studies investigated the effect of FR on PPT and no study examining the effect of FR prior RT it is important to investigate further on this topic.

Regarding performance, previous studies have focused on the effects of FR on maximal power and maximal strength tests such as jump height (12, 21) and isometric peak force (12, 26, 33). For example, Behara and Jacobson (4), found no significant effect on peak and average isometric leg extension torque following by one minute of FR for the hamstrings, quadriceps, and gluteus muscles when compared to control and dynamic stretching conditions. MacDonald et al. (26) found no significant difference in peak isometric leg extension force, rate of force development, and rectus femoris activity following two sets of one minute of FR for the quadriceps as compared to control condition. However, few studies have focused on the effect of FR on multiple sets of RT. To the authors' knowledge, only two known studies have observed a decrease in the maximum repetition performance when different durations of FR protocols (60, 90, and 120 seconds of FR) were performed between (inter-rest) sets of knee extension (27, 28). However, there is still a lack of evidence regarding the effect of FR prior to multiple sets of RT.

Other studies suggested that FR may facilitate fascial hydration due to a mechanical fluid pump or by changes on arterial function (17, 30). For example, Okamoto et al. (30) observed an increase on brachial-ankle pulse wave velocity and plasma nitric oxide concentration after a bout of FR of the major muscle groups. Additionally, Hotfiel et al. (17) observed that arterial blood flow of the lateral thigh increased after and 30 minutes after three sets of 45 seconds of FR. It is reasonable to speculate that such increase in blood flow induced by FR, previously described, may enhance the acute muscle swelling "pump" caused by multiple sets of resistance training. In addition, the aforementioned concept of the combination of a neural modulation on muscle tone and peripheral alterations of the mechanical tissue properties might help to explain eventual changes in MT induced by FR-protocols.

Thus, the purpose of this study was to evaluate the acute effect of two different durations (one and three-minute) of FR protocols on knee extension total load lifted (TLL), PPT, and muscle thickness. The hypothesis based on previous studies was that one and three minutes of FR will reduce the number of repetitions and the TLL in multiple sets of knee extension (27, 28) and increase PPT (2, 19, 31). To the best of the author´s knowledge, no study investigated the acute effect of FR on muscle thickness, however, we hypothesized that FR would be able to significantly increase muscle thickness after multiple sets of RT.

METHODS

Participants

Nine resistance-trained males (age: 24.8 ± 5.2 years [range 19-29 years]; height 177 ± 7 cm; total body mass 77.7 ± 6.2 kg; RT experience: 4.3 ± 0.5 years) volunteered for the study. The sample size was justified by *a priori* power analysis in G*Power software (Version 3.1.9.2; Universität Kiel, Kiel, Germany) based on a pilot study where the vastus lateralis thickness was assessed as the outcome measure (control condition vs foam rolling one minute) with a target effect size difference of 0.75, an alpha level of 0.05, and a power (1 – β) of 0.80 (10). Accordingly, the sample size required to achieve 80% power was eight subjects. Subjects were resistance-trained and performed RT on a minimum of three days per week for at least one year. All subjects performed (minimum frequency of once a week) the knee extension exercise at least one year before entering the study. Subjects also had to be free of any musculoskeletal injury within the past six months before the intervention. This study was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science and all subjects read and signed an informed consent document approved by the Research Ethics Committee of the local university (Protocol: 2.527.071) (29).

Protocol

A randomized within-subject design was used to compare the acute effect of foam rolling on quadriceps femoris muscle thickness and performance after multiple sets of knee extension (KE). All subjects performed four sessions separated by one week within-sessions. The first session was used for testing and familiarization. Anthropometric data (age, height, total body mass, and humerus length) were collected and a test for ten repetitions maximum (10RM) was performed for the knee extension. The 10RM test was performed according to guidelines established by Haff and Triplett (13). The following three sessions were randomized among subjects: control (CON), one minute of foam rolling (FR1), and three minutes of foam rolling (FR3). During each experimental condition, PPT and muscle thickness of vastus lateralis and rectus femoris were measured precondition, two post-condition (only for PPT) and two minutes after five sets of 10RM of knee extension with two minutes of rest interval between sets (Figure 1).

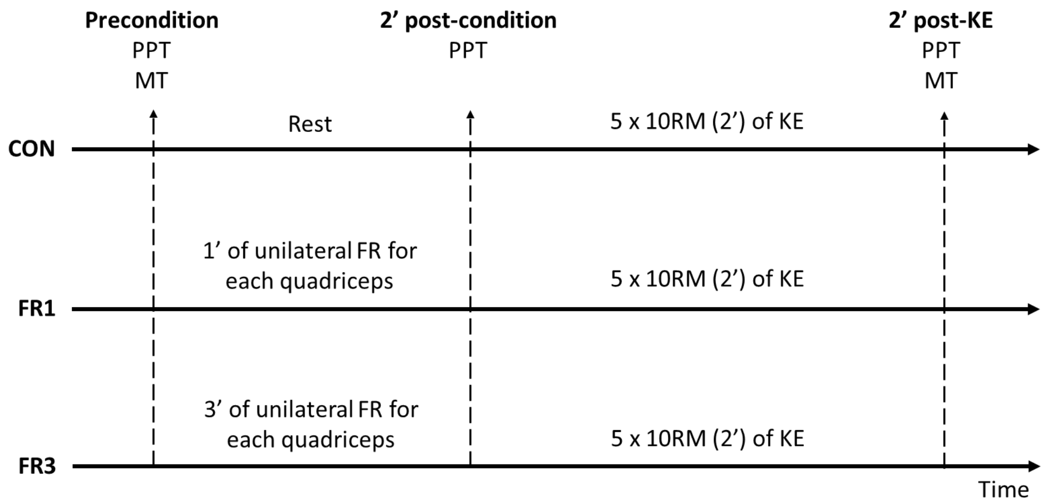

Figure 1. Experimental design. CON = control, FR1 = one minute of foam rolling, FR3= three minutes of foam rolling, MT = muscle thickness, PPT = Pressure Pain Threshold, KE = Knee Extension.

The subjects foam rolled on the quadriceps femoris (QF) unilaterally on a foam roller (Brand: Trigger Points, model: GRID®, Yokohama, Japan). The foam roll (33 cm length x 14 cm diameter) was composed by a hard-hollow core covered by a 15 mm thick layer of ethylene vinyl acetate. The subjects were instructed to perform the myofascial release as previously described by McDonald et al. (26). Subjects were instructed to begin in a plank position and place the foam roller at the most proximal portion of the QF of one leg and to laterally place the opposite leg. The equipment adopted was the same during each experimental condition, which was supervised by the same researcher.

The pressure was adjusted by a numerical scale of perception of discomfort adapted from previous studies investigating stretching (26). This scale varies from 0 = no pressure discomfort at all and 100% = maximal tolerable pressure discomfort. They were instructed to roll back and forth one leg at time from the proximal to the distal portion of the QF in one fluid motion and to exert 70 to 90 of subjects' perception of discomfort (Figure 2). They repeated this motion multiple times for one (FR1) or three minutes (FR3). It was allowed one minute of rest between legs in both conditions. A mat was placed under the roller for each experimental condition in order to prevent an eventual lateral sliding of the implement.

Figure 2. Foam rolling technique.

All subjects performed five sets of 10RM with two minutes of rest between sets for the knee extension exercise (Portico Fitness Inc., Itatiba, SP, Brazil). They were positioned seated with the hip and knee flexed at 90° and were instructed to perform all repetitions from 90° of knee flexion to 0° of knee extension. All sets were conducted to the point of momentary concentric muscular failure, operationally defined as the inability to perform another concentric repetition while maintaining adequate form. If the voluntary muscular failure occurred before ten repetitions, the load was decreased by 5% for the next set. The cadence of repetitions was conducted in a controlled fashion, with concentric and eccentric actions of approximately 1.5 seconds, for total repetition duration of approximately three seconds. RT sessions were preceded by a specific warm-up consisting of two sets of ten repetitions with 50% of the 10RM load. The total load lifted (TLL: total repetitions x load) was recorded for further analysis.

Vastus lateralis (VL) and rectus femoris (RF) muscle thickness were measured by ultrasound imaging. A trained technician performed all testing using an A-mode ultrasound imaging unit (Bodymetrix Pro System; Intelametrix Inc., Livermore, CA, USA). Following a generous application of water-soluble transmission gel (Mercur S.A. – Body Care, Santa Cruz do Sul, RS, Brazil) to the measured site, a 2.5-MHz linear probe was placed perpendicular to the tissue interface without depressing the skin. Equipment settings were optimized for image quality according to the manufacturer's user manual and held constant across testing sessions. When the quality of the image was deemed to be satisfactory, the image was saved to the computer hard drive and muscle thickness dimensions were obtained by measuring the distance from the subcutaneous adipose tissue–muscle interface to the muscle-bone interface. Measurements were taken on the right side of the body with all subjects in a lying position. Measurements were taken at 50% distal between the greater trochanter and the lateral epicondyle of the femur, as per methods used by Abe et al. (1). To maintain consistency between measurements, each site was marked with a permanent marker on the first day of data collection. To further ensure the accuracy of measurements, at least three images were obtained for each site. If measurements were more than 1 mm different from one another, a fourth image was obtained, and the closest three measurements were then averaged. All images were performed by the experienced researcher who was blind to the experimental protocol performed.

The test-retest typical error of measurement (TEM) for VL and RF are 0.41 and 0.40 mm, respectively. The interclass correlation coefficient (ICC) for VL and RF are 0.999 and 0.995, respectively. The coefficient of variation (CV) are 0.6% and 0.7% for VL and RF, respectively.

Pressure pain was induced by a digital algometer (DD20 model, Instrutherm Inc., São Paulo, SP, Brazil) following the recommendations of Chesterton et al. (9). The algometer was pressured by a trained technician at the same spots where the ultrasound images from the vastus lateralis and rectus femoris were taken. Subjects were instructed to say "stop" when a discernable sensation of pain was felt. At this point, the pressure was relieved and the force was recorded in the digital display. Three measurements were taken approximately 10 - 15 seconds apart. The test-retest ICC, CV and TEM for rectus femoris were 0.881, 8.0%, and 0.31 kg, respectively. The ICC, CV, and SEM for vastus lateralis were 0.855, 7.2%, and 0.27 kg, respectively.

Statistical Analysis

The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene tests, respectively. Prior to analysis, all data were log-transformed for analysis to reduce bias arising from non-uniformity error (heteroscedasticity). The mean, standard deviation (SD), and 95% confidence intervals (CI) were used after data normality was assumed. An ANOVA one way (CON vs. FR1 vs. FR3) was used to compare the variables TLL and delta (Δmm) of absolute difference from pre- and post-interventions for muscle thickness (MT) of rectus femoris and vastus lateralis (Δmm = MT post – MT pre). A repeated-measures ANOVA (3x3) was used to compare time effect (pre-, post-two minutes, and post-intervention) and three groups (CON vs. FR1 vs. FR3) in algometer pressure-pain threshold of rectus femoris and vastus lateralis muscles. Post-hoc comparisons were performed with the Bonferroni correction. Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied. In addition, effect sizes were evaluated using a partial eta squared (η^2_p), with < 0.06, 0.06 - 0.14, and > 0.14 indicating a small, medium, and large effect, respectively. All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). The adopted significance was $p \leq 0.05$. In addition, smallest worthwhile chance (SWC) in Δmm MT of rectus femoris and vastus lateralis was calculated by the formula SWC = typical error of the measurement (TEM) x 2 (16). We defined an individual as "responding" to quadriceps foam rolling one with a response greater than 1SWC from zero for increases in Δmm MT of rectus femoris and vastus lateralis; if not, he was considered the non-responder. The subjects were classified as small/moderated responsiveness (1 to 6 SWC) and large responsiveness (> 6 SWC) (7). The figures were formatted in GraphPad Prism version 6.0 software (La Jolla, CA, USA).

RESULTS

No significant main effect of conditions for TLL was observed ($F_{2,24} = 0.006$, $p = 0.994$, $\eta^2_p = 0.001$) (Figure 3). An accumulated TLL (sum of the 5 sets) of 2422 ± 526 kg, 2408 ± 443 kg, and 2435 ± 557 kg was observed for CON, FR1, and FR3, respectively, with no significant difference between conditions.

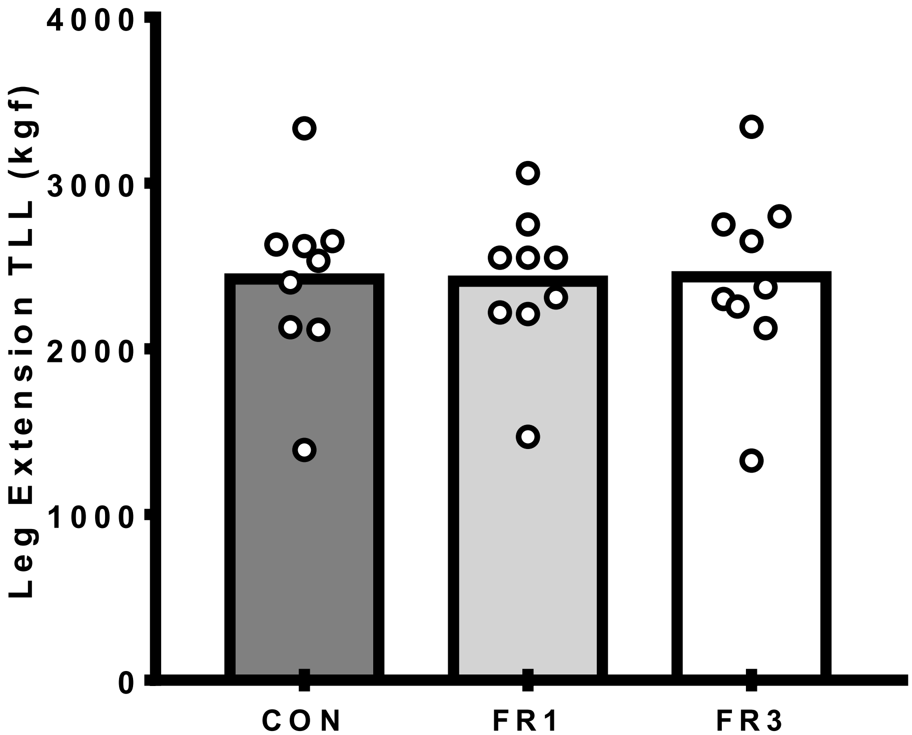

Figure 3. Training load lifted (TLL) on leg extension for control (CON - dark grey bar) and foam rolling for one minute (FR1 – light grey bar) and three minutes (FR3 – white bar).

No significant main effect between conditions was observed in Δmm rectus femoris muscle ($F_{2,24} = 1.688$, $p = 0.206$, $\eta^2_p = 0.123$) (Figure 4A). There was a significant main effect between conditions in Δmm vastus lateralis muscle ($F_{2,24} = 68.379$, $p = 0.001$, $\eta^2_p = 0.851$). FR3 condition was significant greater when compared to CON ($p = 0.001$, CI95% differences = 12.4 to 20.5 mm) and FR1 ($p = 0.001$, CI95% differences = 12.3 to 20.6 mm) (Figure 4B).

The individual analyses showed that nine subjects (100%) in FR3 presented large responsiveness in Δmm vastus lateralis muscle and five subjects (55% of sample) in rectus femoris (Figure 4A). For FR1, three (33%) and one (11%) subjects were large responsiveness in Δmm vastus lateralis and rectus femoris, respectively. For CON condition, one subject (11% of sample) in each muscle presented large responsiveness.

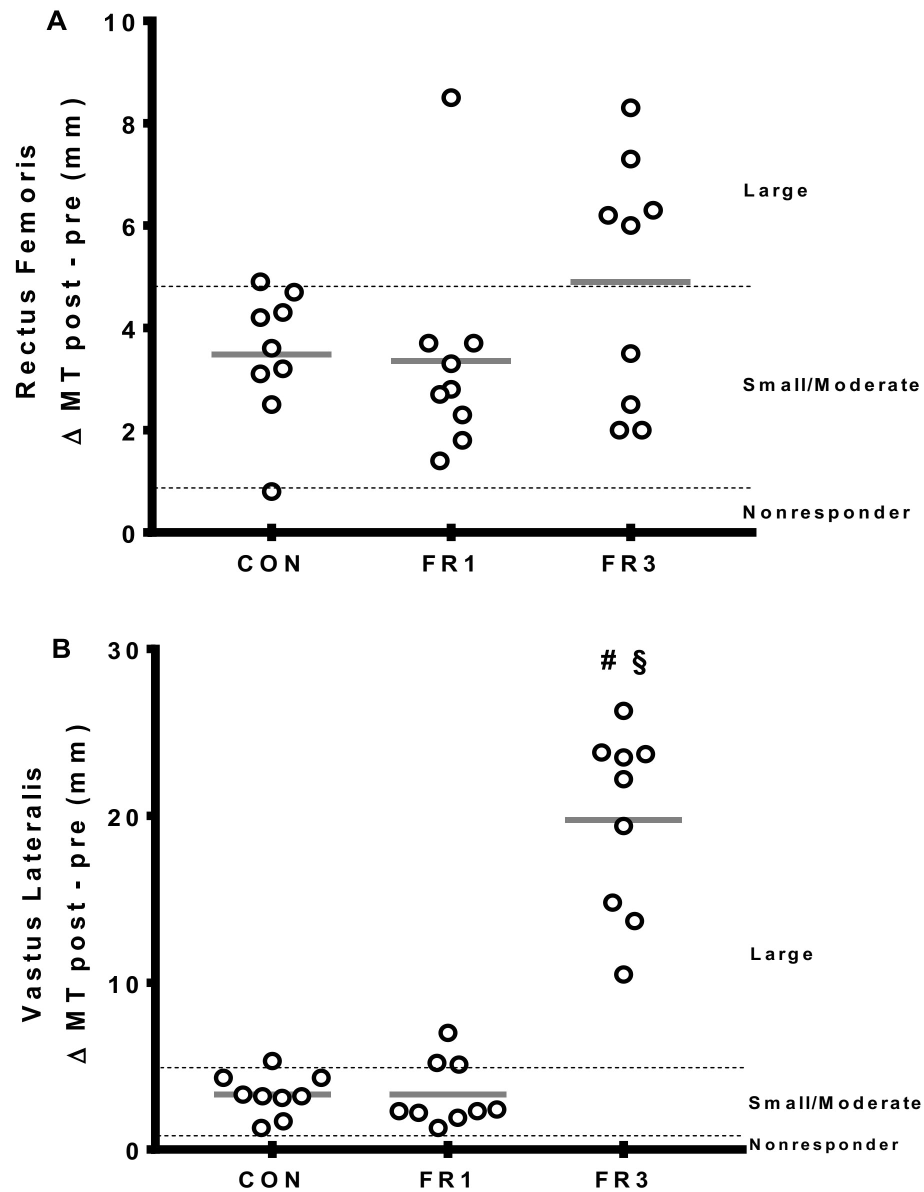

Figure 4. Univariate scatterplot graph comparison for control (CON) and foam rolling for 1-minute (FR1) and 3-minutes (FR3) on muscle thickness (MT) of the rectus femoris (A) and vastus lateralis (B). Delta (Δmm – raw values) of the absolute difference between pre- and post-intervention for MT. Grey lines indicate means. Dashed lines indicate "cut-points" for responsiveness (see Methods). #Significantly greater than the control ($p < 0.05$). §Significantly greater than the FR1 ($p < 0.05$).

A significant main effect of time ($F_{2,16} = 5.850$, $p = 0.012$, $\eta^2_p = 0.422$) was observed for pressure pain threshold (PPT) in rectus femoris muscle. No significant condition x time interaction was observed ($F_{4,32} = 1.043$, $p = 0.401$, $\eta^2_p = 0.115$). There was a significant difference between pre- and post-intervention for CON ($p = 0.027$, mean ± CI 95% difference = 1.11, 0.13 to 2.09 kg) and pre- vs post two-minutes for FR3 ($p = 0.044$, mean ± CI 95% difference = 0.84, 0.02 to 1.67 kg) only for rectus femoris muscle. There was no significant main effect for time ($F_{2,16} = 1.166$, $p =$

0.337, η^2_p = 0.427) and group x time interaction ($F_{4,32}$ = 1.035, p = 0.376, η^2_p = 0.120) for rectus femoris muscle (Table 1).

Table 1. Algometer pressure-pain threshold of rectus femoris and vastus lateralis muscles in pre-, post-two minutes, and post-intervention.

Variables	Pre-condition	Two Minutes Post (condition)	Two Minutes Post (knee extension)	ANOVA 3x3 time *P-value*	time*group *P-value*	η^2_p
Rectus Femoris (kg)						
CON	5.41 ± 1.08	5.60 ± 0.58	6.53 ± 1.41*	0.027	0.401	0.115
FR1	5.53 ± 1.40	5.90 ± 0.52	6.00 ± 1.52	0.288		
FR3	5.76 ± 1.25	6.60 ± 1.23*	6.42 ± 0.98	0.044		
Vastus Lateralis (kg)						
CON	5.47 ± 1.07	5.22 ± 0.72	5.93 ± 1.31	0.281	0.337	0.127
FR1	5.01 ± 1.56	5.47 ± 0.72	5.52 ± 1.25	0.290		
FR3	5.69 ± 1.46	6.20 ± 1.38	5.81 ± 1.33	0.302		

*Significantly greater than the corresponding pre-condition value (p < 0.05). Control (CON), myofascial release for one minute (FR1), and three minutes (FR3) (mean ±SD).

DISCUSSION

The aim of the present study was to evaluate the acute effect of two different durations (one and three minutes) of FR protocols on knee extension TLL, PPT, and muscle thickness. Overall, one and three minutes of FR did not affect the total load lifted in multiple sets of knee extensors. Additionally, three minutes of FR caused a greater increase in the vastus lateralis muscle thickness after five sets of KE and improved the pain pressure threshold.

Contrary to the initial hypothesis, the FR-protocols did not affect the TLL on knee extension exercise (KE). These results are partially in consensus with the scientific literature. Monteiro and Corrêa Neto (27) and Monteiro et al. (28) observed a decrease in the maximum number of repetitions performed on KE when FR were performed between sets. However, some methodological differences must be stressed in an attempt to explain these different results, especially regarding the characteristics of the participants. While in the present study, only men were included, the sample in Monteiro et al. (28) was composed exclusively by females. Then, one can assume that the deleterious effects of FR in the performance of multiple RT sets might be gender-dependent. Additionally, the RT experience in Monteiro et al. (28) was not specifically described, while in our study participants presented large experience with RT. Therefore, possible influences of training level in FR-acute responses must not be discarded. Also, for both Monteiro and Corrêa Neto (27) and Monteiro et al. (28), volunteers were instructed to roll the legs bilaterally and to apply the maximal possible pressure, which might also help to further understand these distinct results.

The present findings are similar to others that did not observe negative effects of FR on strength-dependent activities (4, 12, 21, 26, 33). Behara and Jacobson (4) found no significant difference in peak and average isometric leg extension torque after FR for one-minute for hamstrings, quadriceps, and gluteus as compared to control and dynamic stretching conditions. MacDonald et al. (26) found no significant difference in peak isometric leg extension force, rate of force development, and rectus femoris activity following two sets of FR for one-minute on quadriceps femoris when compared to control condition.

Considering the fascial tension transmission function, the deep fascia has a continuous connection with the muscular tissue which allows the force transmission and it is closely dependent on the slide between the fascial layers (11). In addition, the fascial tissue has special cells, the myofibroblasts, which assist in its tensional transmission and are controlled by the autonomic nervous system (32). This is a key point to note: FR release promotes a thixotropic effect on fascial tissue, reducing afferent excitability, that contributes to local mechanisms of increased blood flow and tissue slide, as well as myofibroblast contraction, theoretically explaining the maintenance of the total volume even after a longer period-FR protocol (5).

There was an increase on rectus femoris PPT following three minutes of FR, but no between-condition differences were observed, which partially confirm our initial hypothesis. The present results are in accordance to previous studies indicating local increase on PPT after a bout of FR (2, 19, 31). Fascial components play a fundamental role in myofascial pain mechanisms. These components of tissue are rich in proprioceptors, Ruffini's and the Pacini's corpuscles, as well as glycosaminoglycans, proteoglycans and hyaluronic acid conferring viscosity to the extracellular matrix (11). Therefore, the fascia can be considered a sense organ of human mechanics (6). Under certain conditions where there is a reduction of slide transmission tension and viscosity of fascia layers, it becomes dehydrated and over tensioned, which produces a nociceptive hypersensitivity of its components favoring the sympathetic action (23). Possibly, FR might modulate pain perception due to due to activation of global pain modulatory responses such as diffuse noxious inhibitory control, gate control theory and increased parasympathetic nervous system relaxation (5). In addition, local mechanisms as an elevated friction-related tissue temperature and the shearing stress from rolling can decrease intracellular and extracellular fluid viscosity, providing less resistance to movement and influencing the pain perception (5).

The acute cell swelling response was analyzed in the present study through the delta (Δmm) of absolute difference from pre- and post-interventions for muscle thickness (Δmm = MT post – MT pre). The acute change in muscle thickness (i.e. acute swelling) is hypothesized to be a shift of intracellular fluid, given that the change in muscle thickness occurs with a concomitant decrease in plasma volume (25). The cell swelling response has been proposed as a mechanism that favorably impacts the net protein balance (20). This increase in muscle swelling would be detected by an intrinsic volume sensor which would result in the activation of anabolic pathways (24). Since swelling is a purposed mechanism that impacts net protein balance observed with an acute bout of RT and a significant positive correlation was found between muscle swelling and muscle hypertrophy, it is important to better understand if there are potential differences in RT routines (e.g., FR before RT bout) regarding the acute swelling response (15).

Confirming the initial hypothesis, the results of this study showed a greater increase on Δmm vastus lateralis for FR3 when compared to CON and FR1 conditions. Moreover, the individual analyses showed that nine subjects (100% of sample) in FR3 presented large responsiveness in Δmm vastus lateralis, while only three (33%) and one (11%) subjects presented large responsiveness for FR1 and CON, respectively. For Δmm rectus femoris, no between-condition difference was observed. Comparisons between the results of the present study with the specific literature are limited, since no investigation aimed to assess the responses of MT following FR-protocols. Then, the causes of distinct responses between the quadriceps muscles (rectus femoris and vastus lateralis) observed cannot be directly addressed. However, it can be speculated that the increases in MT of rectus femoris were not different between conditions due to a non-significant increase in electromyography (EMG) activity for this muscle, as previously reported by MacDonald et al. (26). However, this hypothesis must be clearly investigated in future studies adopting EMG analysis for the quadriceps muscles, helping to clarify these findings and raising possible correlations between these variable and increases in MT during FR trials.

The individual analyses showed that five subjects (55%) presented large responsiveness in FR3, while only one (11%) subject was large responsiveness for FR1 and CON. Thus, taken together, these results (mean and individual) imply that for a possible increase in acute muscle swelling, a higher FR volume may result in a more homogeneous response.

It is plausible that the pressure and the friction caused by the FR have increased the temperature and released the myofascial restrictions (3). Ichikawa et al. (18) observed a decrease in fascia and vastus lateralis stiffness after four minutes of manual massage. Another possible mechanism is the tissue hydration. The pressure applied by the FR soak the myofascial complex with fluid, improving the movement between the layers of fascia and increasing the blood flow in the region (22). Okamoto et al. (30) observed a decrease in arterial stiffness and an increase in plasma nitric oxide concentration. Additionally, Hotfiel et al. (17) observed an increase in blood flow to the lateral aspect of the thigh after an FR protocol. Taken together, it is plausible to hypothesize that all these physiological mechanisms were potentiated through the higher FR-volume condition (FR3), which in turn may explain the greater muscle swelling observed in comparison to CON and FR1.

The present study has some limitations. First, the study investigated only male resistance-training subjects. Therefore, the results may not be extended to other population or training status. Second, even though the sample size was sufficient to reduce possible type 2 error, the adoption of a large number of participants could eventually induce different results, especially regarding MT, in which mixed results were observed for the two quadriceps muscles (rectus femoris and vastus lateralus). Third, vastus lateralis and rectus femoris images were taken from a specific site; it is possible that different regions of the same muscle might present different responses. Additionally, data from pre-intervention nutritional habits were not collected, which may have influenced some of performance and metabolic outcomes. However, participants were asked to maintain their usual nutritional habits in order to minimize possible influences of such variable. It is also important to stress that a mat was placed under the roller in order to reduce lateral slide from the implement. However, it is inconclusive if the absence of such material could induce any difference in the outcomes of the study. Finally, the present findings cannot be extrapolated to a chronic context. Then, the authors encourage future interventions aiming to assess chronic effects of FR combined with RT (i.e., muscle strength and hypertrophy). In conclusion, the present study shows that resistance-trained subjects can accumulated the same total training volume when performing FR before RT. Moreover, FR for three minutes before RT increase the acute muscle swelling without increase PPT after RT. Those findings may have relevant practical implications for those aiming to maintain a higher training volume and a more pronounced metabolic stress (muscle swelling). In such case, the use of FR for 3 minutes before RT must can be a viable option.

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