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ORIGINAL RESEARCH

EFFECT OF DIFFERENT FOAM ROLLING VOLUMES ON KNEE EXTENSION FATIGUE

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ABSTRACT

Background: Foam rolling (FR) is a common intervention utilized for the purpose of acutely increasing range-of-motion without subsequent decreases in performance. FR is characterized as an active technique which subject performs upon themselves. Thus, it is believed that the accumulated fatigue can influence whether the task can be continued.

Purpose: To analyze the effect of different foam rolling volumes on fatigue of the knee extensors.

Methods: Twenty-five recreationally active females (age 27.7 ± 3.56 y, height 168.4 ± 7.1 cm, weight 69.1 ± 10.2 kg) were recruited for the study. The experiment involved three sets of knee extensions with a pre-determined 10 repetition maximum load to concentric failure. Then, subjects performed the control (CONT) and foam rolling (FR) conditions. FR conditions consisted of different anterior thigh rolling volumes (60-, 90-, and 120-seconds) which were performed during the inter-set rest period. After that, the fatigue index was calculated and compared between each experimental condition. Fatigue index indicates how much (%) resistance the subjects experienced, calculated by the equation: (thidset/firstset) x 100.

Results: Fatigue index was statistically significantly greater (greater fatigue resistance) for CONT compared to FR90 (p = 0.001) and FR120 (p = 0.001). Similarly, higher fatigue resistance was observed for FR60 when compared to FR120 (p = 0.048). There were no significant differences between the other conditions ($p > 0.005$).

Conclusion: The finding of foam rolling fatigue index decline (less fatigue resistance) as compared to control conditions may have implications for foam rolling prescription and implementation, in both rehabilitation and athletic populations. For the purposes of maximum repetition performance, foam rolling should not be applied to the agonist muscle group between sets of knee extensions. Moreover, it seems that volumes greater than 90-seconds are detrimental to the ability to continually produce force.

Level of evidence: 2b

Keywords: Massage, neuromuscular fatigue, self-myofascial release, strength

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INTRODUCTION

Foam rolling (FR) is a common intervention utilized for the purposes of acutely increasing range-of-motion (ROM) without subsequent decreases in performance.[1,2] Therefore, it is commonly used during the peri-workout period; that is, before, during, or after workouts in athletes and non-athletes. However, the effects of this practice have not yet been fully elucidated. FR has been shown to bring about acute increases in ROM without decreases in performance[1,3,4], reduce delayed onset muscle soreness after exercise[5,6], and improve vascular endothelial function and reduce arterial stiffness.[7] FR is characterized as an active technique which subject performs upon themselves. Thus, it is believed that the accumulated fatigue could negatively influence the ability to continue activity.[8-10]

Most studies have focused on ROM effects and strength activities (i.e. maximum repetition performance); little research has focused on the effects of FR on fatigue during resistance training. To the authors' knowledge, only two studies to date have investigated the effects of FR on a fatigue during resistance training. The first study observed maximum repetition performance of knee extension after anterior thigh inter-set FR in different volumes (60-, 90- and 120-seconds).[11] The second study utilized hamstring inter-set FR in different volumes (60- and 120-seconds) and observed maximum repetition performance of knee extension.[12] Both studies found a dose-response decrease in repetition performance with greater amounts of FR volume. The mechanism by which greater FR dose decreases maximum repetition performance remains unclear.

While foam rolling has been used for various purposes, including warm-up and motion preparation for athletes and non-athletes, there is a lack of evidence regarding the effects of accumulated fatigue on maximum repetition performance. Thus, the purpose of this study was to analyze the effect of different foam rolling volumes on fatigue of the knee extensors.

METHODS

Subjects

Twenty-five recreationally active females[13] (Table 1) were recruited for the study. A priori sample size calculation[14] (Effect Size = 3.67; β = 0.95; α = 0.05) using G*Power (Universität kiel, Germany)[15] found that eight subjects would be adequate, however, in order to increase statistical power, twenty-five were recruited. Subjects performed the resistance procedures in the luteal phase of the menstrual cycle.[16] Before the experimental protocols anthropometric data were collected including body mass (Techline BAL – 150 digital scale, São Paulo, Brazil), and height (Stadiometer ES 2030 Sanny, São Paulo, Brazil).

Table 1. *Means ± SD for subject's characteristics.*

Age (years)	27.7 ± 3.56
Height (cm)	168.4 ± 7.1
BM (kg)	69.1 ± 10.2
BMI (m²/kg)	24.2 ± 2.0
RTE (months)	23.0 ± 6.5
KE 10RM test (kg)	70.7 ± 11.0
KE 10RM retest (kg)	71.4 ± 11.2

BM = Body Mass; BMI = Body Mass Index; RTE = Resistance Training Experience; KE = knee extension.

Subjects were included if they were experienced in the use of knee extension machine exercises for at least one-year prior the experiment, 3-4 session per week, and using loads that allowed participants to perform to 8-12 maximum repetitions. Subjects were free from any functional limitations or medical conditions that could have compromised their health or confounded results of the study. During the thirteen-day period of data collection the subjects were instructed not to engage in any lower body resistance training exercise or other strenuous activities. Prior to the study all participants were provided verbal explanation of the study and read and signed informed consent and Physical Activity Readiness Questionnaire.[17] All procedures were in accordance with Declaration of Helsinki. The local ethics committee approved the study (57023616.7.0000.5257/16).

Procedures

Ten repetition maximum testing

Ten repetition maximum (10RM) testing and retesting was performed using a methodology similar to the protocol of Bentes et al[18] with an interval of 48 hours between the two days. A maximum of three trials were allowed per testing session, separated by three minutes of recovery. The higher load between the two testing days was considered as the 10RM load. Reliability of the method to determine the 10RM load was confirmed by calculating the intraclass correlation coefficient (ICC). Subjects initially performed a standardized warm up consisting of fifteen repetitions of knee extensions with self-selected load, approximately 50% of a normal training load. After the warm up, ten-repetition maximum testing was performed. Pace of the knee extension exercise was standardized using a metronome (Metronome Plus, version 2.0, M&M System, Braugrasse, Germany) to two seconds for both phases of the movement. In an effort to minimize variability in performance between individuals, the following strategies were adopted:[19] a) all subjects received standardized instructions about the exercise technique and data collection, b) subjects received feedback as to their technique and were corrected if appropriate, and c) all subjects were verbally encouraged. The knee extension apparatus used for 10 RM testing and during the experimental sessions was the same (Selection Line Leg Extension, Technogym, Cesena, Italy).

Foam rolling

Foam rolling composed of a hard inner core enclosed in a layer of ethylene vinyl acetate foam was used (The Grid Foam Roller, Trigger Point Technologies, 5321 Industrial Oaks Blvd., Austin, Texas 78735, USA). This kind of foam roller has been shown to produce more pressure on the soft tissue than those made out of polystyrene foam.[20] FR was performed bilaterally in anterior thigh in a prone position while maintaining the legs extended (in contact with the foam roller), but relaxed. Subjects were instructed to move their body back and forward to apply pressure between the acetabulum and patellar tendon. As per randomization, FR was performed during the inter-set rest period for 60-, 90-, or 120-seconds. For better representation of real work training environments, subjects were free to choose the pace at which they performed the foam rolling.

Experimental Approach to the Problem

A randomized (aleatory entry in latin square format), cross-over, within-subjects design was used

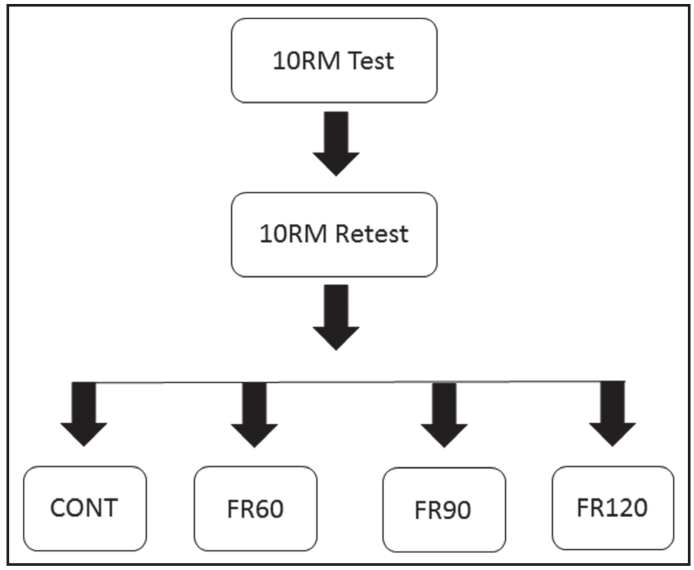

Figure 1. *Experimental protocols design. CONT = control experimental condition; FR60 = foam rolling for 60 seconds; FR90 = foam rolling for 90 seconds; FR120 = foam rolling for 120 seconds.*

(Figure 1). Subjects visited the laboratory on six occasions during a thirteen-day period with at least forty-eight hours between the visits. During the first two visits the subjects underwent a 10RM testing and retesting, respectively. Following, four experimental visits followed in a randomized order, which included: 1) control experimental condition (CONT) with four-minutes passive rest interval, 2) foam rolling for 60 seconds (FR60), 3) foam rolling for 90 seconds (FR90), and 4) foam rolling for 120 seconds (FR120). Each experimental session consisted in three sets of knee extension at 100% of 10RM load to concentric muscle failure, interspersed by four-minute rest intervals, with the goal of completing the maximum number of repetitions without losing the movement pattern. FR was performed between sets on the inter-set rest period.

Statistical analyses

Data are presented as means ± standard deviations. Initially, the neuromuscular fatigue index (FI) was calculated using the equation proposed by Dipla et al.[21], where a higher percentage value (%) indicates a superior fatigue resistance: FI = (thirdset / firstset) x 100. Normality and sphericity were tested using a Shapiro Wilks test and homoscedasticity was confirmed by a Mauchly's test. Repeated measures ANOVA was used to compare the fatigue index across four conditions (CONT, FR60, FR90 and FR120). If a significant effect of condition was found, a Tukey HSD post-hoc test was used to identify significant differences between individual conditions. All analyses were performed using SPSS version 20 (SPSS Inc., Chicago, IL, USA) and an alpha level of 0.05 was used.

RESULTS

The reliability of 10RM testing was determined by calculating an intraclass correlation coefficient for women ($r = 0.981$, 95%CI = 0.966 to 0.996).

There was a difference in mean fatigue index across the four conditions ($F = 8.184$; $p < 0.001$) as shown in Table 2. Fatigue index indicating greater fatigue resistance for CONT when compared to FR90 ($p = 0.001$) and FR120 ($p < 0.001$). Similarly, higher fatigue resistance was observed for FR60 when compared to FR120 ($p = 0.048$). There were no significant differences between the other conditions ($p > 0.005$).

DISCUSSION

The purpose of this study was to analyze the effect of different foam rolling volumes on fatigue of the knee extensors. Fatigue indices indicating greater fatigue resistance were seen in CONT comparee to FR90 ($p = 0.001$) and FR120 ($p < 0.001$). Similarly, higher fatigue resistance was observed for FR60 when compared to FR120 ($p = 0.048$). These results confirmed the initial hypothesis, which suggested that higher volumes of FR promote higher muscular fatigue. The results are in accordance with the works of previous authors who investigated the effects of rest interval on fatigue[9,22,23] and also with previous unpublished work by the authors on inter-set foam rolling applied to the antagonist muscle group;[11,12] which found a dose-response decrease in repetition performance with greater volume of FR (120 > 90 > 60).

Table 2. *Means ± standard deviations for each knee extension condition*

	Set 1	Set 3	FI
CONT	10.24 ± 0.43	9.48 ± 0.50	98.48 ± 5.80
FR60	9.64 ± 0.48	8.56 ± 0.86	88.68 ± 9.01
FR90	10.00 ± 0.57	8.52 ± 0.65	84.44 ± 7.54#
FR120	9.60 ± 0.5	8.00 ± 0.64	83.16 ± 6.95#*

CONT = experimental control condition; FR60 = foam rolling for 60 seconds; FR90 = foam rolling for 90 seconds; FR120 = foam rolling for 120 seconds;FI = fatigue index. # Statistically significant difference between FR90 and FR120; * Statistically significant difference between FR60 and FR120.

Maximum repetition performance depends directly on the ability to maintain intensity during set progression.[24] Several factors can influence the maintenance of task performance (fatigue). Maia et al[22] observed that the exercise order had a negative influence on maximum repetition performance. Tibana et al[9] observed the same results on rest interval less than 30 seconds (120 > 60 > 30) in high intensity and low range between sets. Therefore, it is possible that the fatigue generated by the FR activity may have interfered in the knee extension performance. Monteiro et al.[12] observed a dose-dependent response in which longer durations of foam rolling the hamstrings hindered maximum repetition performance.

The mechanisms by which FR works are not fully understood. However, a number of underlying mechanical and neurophysiological[1] mechanisms have been proposed and investigated. Changes in fascial components (i.e. adhesions, piezoelectricity, myofascial trigger points, and viscoelastic properties of tissue)[25] influenced by collagen remodeling and changes in elastin are possible reasons for the ROM and muscle force increases seen after foam rolling.[1,26] However, at present, these mechanisms are not supported by the literature. Secondly, central command response of activation of mechanoreceptors may cause withdrawal of parasympathetic predominance and increase sympathetic activation.[7,27,28] Third, endogenous opioid response may modulate the perception of effort.[11,12,29] Fourth, the mechanoreceptors inside the muscle and fascia may directly influence a decrease muscle tone.[1,30-32] Finally, opioid activity has been implicated during fatiguing conditions acting by attenuating the afferent motor feedback from agonist musculature, resulting in greater power output in the beginning of an exercise, which eventually leads to excess peripheral muscle fatigue.[29]

There are a number of limitations and delimitations to bear in mind when interpreting the results of the present study. First, this present study utilized female subjects, so these results cannot be extrapolated to men. Janot et al[9] indicated that women are more susceptible to fatigue during dynamic contractions. Women have a difference in power output during the different phases of the menstrual cycle and trends powerfully on luteal phase. To minimize these effects, all were tested in the luteal phase.[15] Finally; the pace of each roll on the FR was not controlled. This can be considered as both a limitation and strength of this design. Specifically, the lack of control reduces the internal validity of the results, as the number/duration of rolls during a time period could possibly influence the outcome. Conversely, the freedom to choose the pace duration of each roll enhances to ecological validity of the finding, as it better represents real-life training scenarios.

CONCLUSION

Intraset foam rolling seems to decrease in maximum repetition performance as compared to a control conditions. These findings have implications for foam rolling prescription and implementation, in both athletic and non-athletic populations. For the purposes of maximum repetition performance in females, foam rolling should not be applied to the agonist muscle group between sets of knee extensions. Moreover, it seems that volumes greater than 90-seconds are detrimental to the ability to continually produce force.

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