Influence of Foam Rolling on Recovery From Exercise-Induced Muscle Damage

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Abstract

D'Amico, AP and Gillis, J. Influence of foam rolling on recovery from exercise-induced muscle damage. *J Strength Cond Res* 33(9): 2443–2452, 2019—The purpose of this study was to examine the impact of foam rolling (FR) on recovery from exercise-induced muscle damage (EIMD). Thirty-seven male individuals performed 40 × 15-m sprints, inducing muscle damage. Immediately after sprinting and in the 4 days following, perceived muscle soreness, hip abduction range of motion (ROM), hamstring muscle length, vertical jump (VJ), and agility measures were recorded. Eighteen subjects (mean ± *SD*; age 22.4 ± 2.0 years; BMI [body mass index] 26.9 ± 4.2 $kg \cdot m^{-2}$) foam rolled before testing each day, whereas 19 (mean ± *SD*; age 23.2 ± 3.2 years; BMI 26.3 ± 4.0 $kg \cdot m^{-2}$) served as a non-FR control (CON). Measurements recorded during the 5 days of recovery from the repeated sprint protocol were compared with week 1 baseline measurements. The area under the curve (AUC) was calculated by summing all 5 scores as they changed from baseline measurement, and these data were compared by condition using a 2-tailed Mann-Whitney *U*-test (alpha level = 0.05). Perceived soreness, hip abduction ROM, hamstring muscle length, and VJ were not significantly different between groups ($p \geq 0.25$). Agility was less impaired in the FR condition ($p = 0.0049$) as AUC was higher in CON (2.88 ± 2.45 seconds) than in FR (0.33 ± 2.16 seconds). Based on these data, FR appears to expedite recovery of agility after EIMD instigated by a repeated sprint protocol. Foam rolling may be useful for athletes requiring adequate agility who need to recover quickly from demanding bouts of exercise.

Key Words agility, flexibility, muscular soreness, myofascial release, sprinting

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Introduction

Exercise-induced muscle damage (EIMD) typically follows demanding, novel exercise where large volumes of eccentric contractions are performed, commonly occurring with decelerating activities like walking down stairs, running downhill, or lowering heavy objects (12). Exercise performed in this manner may result in intracellular muscle damage, which can impair muscle function and cause delayed onset muscle soreness (DOMS) (1). In addition, EIMD may result in swelling and inflammation, along with an increase in proteins in the blood (18). The mechanisms underlying EIMD are unclear, but mechanical and metabolic pathways are each thought to contribute (39). For example, a proposed mechanical pathway described by Proske and Morgan (30) involves disruption to the sarcomere due to a high degree of tension placed on myofibrils. Comparatively, a proposed metabolic pathway described by Tee et al. (37) involves a delayed inflammatory response, oxidative stress, and the impairment of excitation-contraction coupling due to a disruption of calcium homeostasis (37).

A certain degree of EIMD is a normal and potentially beneficial stimulus for the physiological adaptations associated with chronic exercise (32). However, excessive damage may impair an athlete's ability to train with the intensity necessary for further adaptation (32). Thus, interventions capable of alleviating EIMD symptoms may benefit athletes during certain phases of a periodized training plan. Alternatively, acute performance likely takes priority over chronic adaptations during the competition period. If EIMD is an unavoidable byproduct of an athlete's competitive schedule, an intervention reducing its detrimental effects could aid performance. Foam rolling (FR), a form of self-myofascial release (23), may help athletes accomplish these goals.

Foam rolling is a commonly used technique that requires individuals to use their own body mass on a foam roller to apply pressure to the soft tissue (22). Limited data provide a conflicting view of FR's influence on acute performance (17,28). Healey et al. (17) found that FR did not directly benefit acute performance, but may have delayed sensations of fatigue during exercise. Conversely, Peacock et al. (28) reported performance benefits associated with FR when used in conjunction with dynamic stretching. The literature regarding FR and joint range of motion (ROM) is more extensive and less equivocal. In this case, FR has consistently been found to acutely increase joint ROM (6,7,11,20,21,25,27,33) while preserving strength and power (3,16,23,34,35). As such, researchers have suggested that FR before training or competition is an optimal way to increase ROM, without the potential performance decrements associated with static stretching (23,34). Some researchers have questioned the clinical relevance of these findings (26), whereas others have observed that FR offers little in the way of improved ROM when performed with dynamic stretching (41). Furthermore, heterogeneity of methods among studies hinders the establishment of a consensus on the optimal self-myofascial release program (10), and by extension, the optimal FR program. Although several important questions regarding FR remain, such as optimal bout duration (13), roller density, and tissue pressure (14), the weight of the evidence appears to suggest that FR increases acute ROM.

Recovery from demanding exercise may be another potential benefit of FR. Researchers have suggested that FR may reduce the sensation of DOMS and could expedite the restoration of athletic performance after demanding exercise over a multiple-day span (19,22,29). Three recent investigations explored the influence of FR after high-volume resistance training protocols. The first study in question was conducted by Jay et al. (19). These authors investigated the influence of roller massage on muscle soreness, pain pressure threshold (PPT), and ROM after the induction of DOMS (10 sets of 10 stiff-legged deadlifts). Jay et al. (19) reported significant reductions in muscle soreness and increases in PPT compared with a control (CON). Second, in a between-subject experimental design (10 subjects per condition), MacDonald et al. (22) assessed the efficacy of FR as a recovery tool on various measures, including muscle soreness, flexibility, vertical jump (VJ), and muscle activation before and 24, 48, and 72 hours after EIMD (10 sets of 10 back squat repetitions at 60% 1 repetition maximum [1RM]). These authors reported significant reductions in muscle soreness and improvements in VJ and muscle activation. The third study in question was conducted by Pearcey et al. (29). These researchers used a within-subject experimental design (8 subjects) to assess the efficacy of FR as a recovery tool. The authors measured 30-m sprint time, standing broad jump length, and the time required to run the agility T-test. These measures were obtained before and 24, 48, and 72 hours after EIMD (10 sets of 10 back squat repetitions at 60% 1RM). Four weeks separated the FR condition from the CON condition. The data from this experiment indicated that after EIMD, FR improved sprint time, standing broad jump, and the agility T-test compared with CON. Taken together, the 3 aforementioned studies suggest that FR may enhance recovery after intense, high-volume resistance training.

To our knowledge, there are no studies in the available literature examining FR's influence on recovery from sprinting. Although the findings reported by Jay et al. (19), Macdonald et al. (22), and Pearcey et al. (29) provide insight into FR's influence on EIMD, they are specific to EIMD caused by high-volume resistance training. Exercise-induced muscle damage caused by high-volume sprinting may impact the body in a different manner, potentially influencing some muscles and joints more harshly than those influenced by squats or stiff-legged deadlifts, whereas comparatively sparing others. A unique investigation is warranted given FR's popularity as a purported recovery tool and the preponderance of athletes likely seeking relief from EIMD after high-volume sprinting. Therefore, the purpose of this study was to assess the influence of FR on gross measures of physical performance including agility, VJ, ROM, and perceptions of muscle soreness on recovery from EIMD caused by high-volume sprinting. Our hypothesis was that after EIMD, FR would result in less impairment for agility, VJ, ROM, and decrease perceptions of muscle soreness compared with CON.

Methods

Experimental Approach to the Problem

A counterbalanced, independent-group design was used to assess how FR influences recovery after EIMD. Testing consisted of a repeated sprint protocol designed to induce muscle damage, followed by 5 consecutive days of a non-fatiguing performance test battery. These 5 testing days were preceded by 3 days of baseline tests and familiarization sessions. Dependent variables included perceptions of muscular soreness, hip abduction ROM, hamstring muscle length, VJ, and agility T-test time. Dependent variables were chosen to assess attributes athletes would hope to restore as quickly as possible after muscle damage induced by training, practice, or competition. Within the context of this study, the independent variable was FR after EIMD, or not FR. The dependent variables were used to assess differences in recovery between subjects who foam rolled daily versus those not using any type of recovery modality. A repeated sprint protocol was chosen as the means by which to induce muscle damage because of its demonstrated reliability (43), and the extent to which the findings might pertain to a wide array of sporting scenarios.

Subjects

Eighteen healthy, college-aged male individuals (mean ± *SD*; age 22.4 ± 2.0 years; BMI [body mass index] 26.9 ± 4.2 $kg\cdot m^{-2}$) foam rolled before testing each day, whereas 19 (mean ± *SD*; age 23.2 ± 3.2 years; BMI 26.3 ± 4.0 $kg\cdot m^{-2}$) served as a non-FR CON. Subjects were verbally informed of all procedures, informed of the potential risks and benefits of the study, and if willing to participate, read and signed an informed consent form before participation. All procedures were approved by the Salem State University

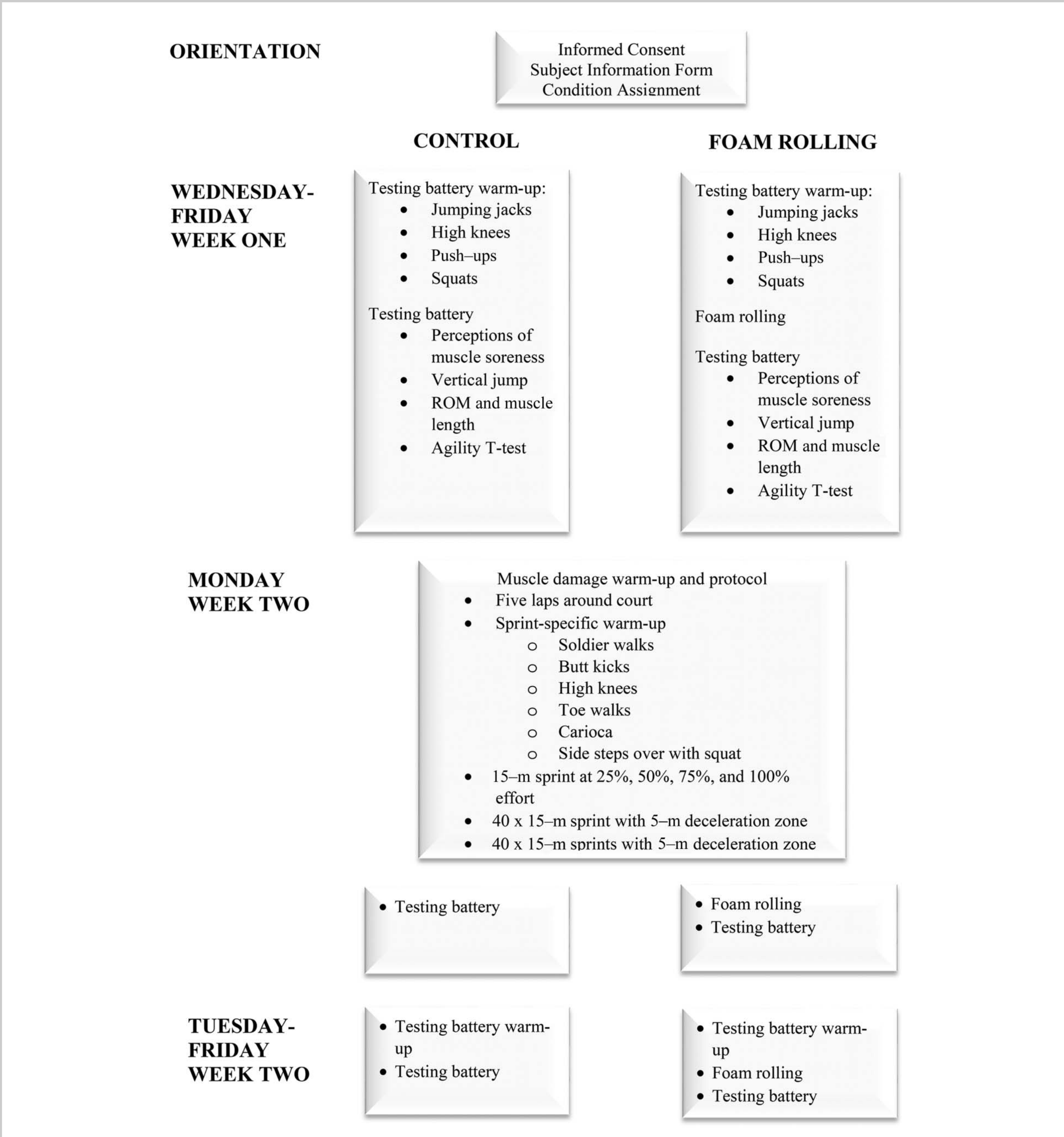

Figure 1. Experimental timeline. ROM = range of motion.

Institutional Review Board. All subjects were aged 18 years or older (range 19–30 years). Based on previous research, approximately 8–20 subjects per condition in a between-subject experimental design were determined as sufficient to observe a significant difference in the primary outcome measure of muscle soreness (19,22,29). Training status was determined at initial contact through informal conversation, without the use of a questionnaire or survey. Potential subjects were excluded if they (a) had a pre-existing injury or muscular soreness or (b) had foam rolled in the past 30 days. Subjects were excluded if they had already participated in similar research, where muscle damage was induced by a repeated sprint protocol. Each subject was instructed to refrain from strenuous physical activity and alcohol consumption for 24 hours before testing.

TABLE 1. Mean (*SD*) subject characteristics at baseline.*

Variable	CON (*n* = 19)	FR (*n* = 18)	*p*
Mass (kg)	81.94 (13.70)	82.88 (14.53)	0.784
Age (y)	23.21 (3.26)	22.44 (1.98)	0.649
Height (m)	1.77 (0.11)	1.76 (0.09)	0.831
BMI ($kg\cdot m^{-2}$)	26.29 (3.84)	26.86 (4.17)	0.533
Muscle soreness (gLMS)	9.03 (9.73)	10.11 (8.98)	0.445
Muscle pain: quadriceps (VAS)	0.29 (0.48)	0.44 (0.57)	0.318
Muscle pain: hamstrings (VAS)	0.55 (0.72)	0.44 (0.48)	0.935
Muscle pain: calf (VAS)	0.47 (0.66)	0.53 (0.55)	0.621
Hamstring muscle length (°)	90.66 (11.43)	86.26 (10.38)	0.377
Hip abduction (°)	46.30 (10.63)	43.53 (9.62)	0.394
Vertical jump height (inches)†	24.71 (4.40)	20.45 (3.09)	0.002
Agility (s)†	10.63 (1.14)	11.63 (1.22)	0.014

*CON = control; FR = foam rolling; BMI = body mass index; gLMS = general labeled magnitude scale; VAS = visual analog scale.
†Significant difference as assessed by the 2-tailed Mann-Whitney *U*-test.

Procedures

This experiment took place over a period of 2 weeks. Student researchers were trained to collect each measurement to ensure reliability. During the first session of week 1, subjects were assigned to either FR or CON in a counterbalanced order. After group assignment, subjects in CON completed a warm-up, followed by a nonfatiguing testing battery that included perception of muscle soreness, hip abduction ROM, hamstring muscle length, VJ, and the agility T-test (described below). Subjects in FR followed the same protocol but were oriented to the FR protocol after the warm-up and before the testing battery. Subjects in CON were provided with identical instructions as FR but were not given any explanation or orientation to the FR protocol. This protocol was followed during each of the subjects' 3 visits to the laboratory during week 1. Testing took place at the same time of day throughout the study to minimize the influence of diurnal variation on performance. Testing was conducted in the same physical spaces in front of the same individuals throughout data collection to control for audience effects. In addition to providing comparison data, baseline testing was conducted more than 3 days to minimize the influence of learning effects during testing the following week. During week 2, subjects attended the laboratory 5 days, once per day, from Monday to Friday. On Monday evening, subjects underwent a repeated sprinting protocol (described below). Ten minutes thereafter, subjects in the experimental group underwent the FR intervention, whereas CON did nothing. Both groups performed the testing batteries immediately thereafter. On the evenings of Tuesday through Friday, both CON and FR performed a standardized, pretesting battery warm-up (50 jumping jacks, 30 high knees [15 per leg], 10 push-ups, and 10 squats). Subjects in FR performed the FR protocol, then immediately performed the testing battery. Subjects in CON immediately performed the testing battery after the warm-up. Details of the experimental design are provided in Figure 1.

Description of the Foam Rolling Intervention. Using a protocol adapted from MacDonald et al. (22), subjects performed 6 FR movements targeting the thigh (quadriceps and hamstrings), gluteus maximus, and gastrocnemius muscles using a high-density foam roller (Theraband; Hygienic Corporation, Akron, OH, USA) on both the right and left legs for two 60-second bouts each. Each roll was timed to a cadence with a metronome allowing for 5 seconds per roll within the 60-second period. In performing exercises for the thigh, subjects were instructed to place their body mass on the foam roller, starting at the proximal aspect of the thigh, and then rolling gradually toward the knee. Once the foam roller reached the distal aspect of the thigh, subjects returned the foam roller to the proximal aspect in 1 fluid motion. This sequence continued for the remainder of the 60-second trial. The FR protocol covered the anterior, lateral, posterior, and medial aspect of the thigh. For the gluteal muscles, each subject was instructed to sit on top of the foam roller, placing both hands on the floor behind them. The subjects crossed their right/left leg over their left/right knee, positioning their body so the left/right gluteal muscle was in contact with the foam roller. Subjects were instructed to undulate back and forth, with the foam roller running in line with the origin (the gluteal surface of ilium, lumbar fascia, sacrum, and sacrotuberous ligament) and insertion (gluteal tuberosity of the femur and iliotibial tract) of the gluteus maximus muscle. For the gastrocnemius muscles, the subjects were instructed to place their body mass on the proximal aspect of the gastrocnemius muscle and then gradually work down the calf using smooth, fluid movements, moving the foam roller from the proximal to the distal aspect of the muscle.

Description of Muscle Damage Protocol. Before the muscle damage protocol on Monday evening, subjects performed a general warm-up consisting of 5 laps around the perimeter of a basketball court followed by a sprinting-specific dynamic warm-up consisting of soldier walks, butt kicks, high knees, walking on toes, cariocas, and side steps over

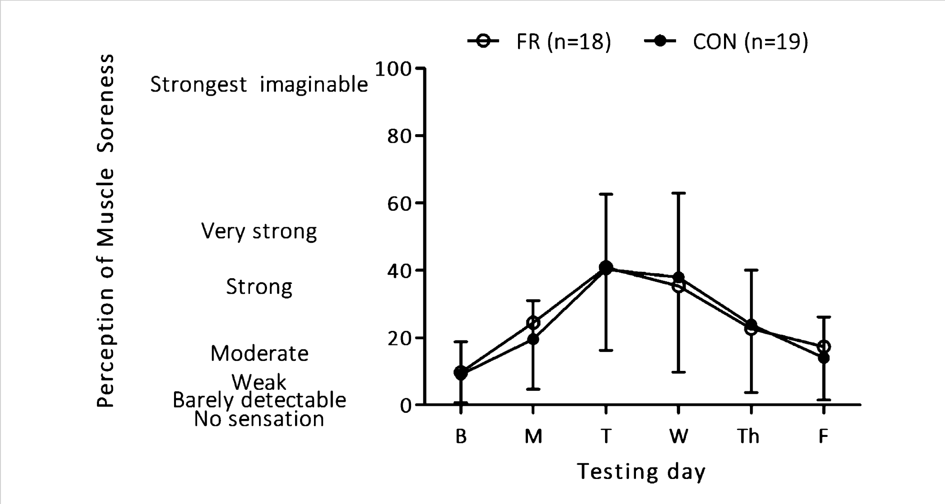

Figure 2. Perception of muscle soreness. Mean perception of muscle soreness approached "strong" to "very strong" across both conditions, with no significant difference observed ($p > 0.05$). FR = foam rolling; CON = control.

with a squat. Subjects then completed four 15-m sprints progressing from 25% of maximal intensity (sprint 1) to 50% (sprint 2), to 75% (sprint 3), and to 100% (sprint 4). This sprinting-specific warm-up performed before the muscle damage protocol differed from the aforementioned warm-up used on other testing days. The sprinting-specific warm-up (Figure 1) was intended to reduce the likelihood of a running injury, whereas the pretesting battery warm-up was intended to promote more generalized preparedness and increases in tissue temperature.

Repeated sprinting was used to induce muscle damage in subjects. Specifically, subjects completed forty 15-m sprints with a 5-m deceleration zone. Woolley et al. (43) observed that this protocol caused muscle damage in physically active men with a mean (*SD*) age, height, and mass of 27 (±3) years, 1.78 (±0.06) m, and 78.4 (±7.5) kg, respectively. Some commonly used methods of inducing muscle damage are using an isokinetic dynamometer, downhill running, and drop jumping. Compared with drop jumping, Wooley et al. (43) observed that the sprinting protocol caused more muscle damage, most likely because of the 5-m deceleration zone.

Perception of Muscle Soreness. A PainTest FPN 100 Algometer (Wagner Instruments, Greenwich, CT, USA) was used to measure muscle soreness of the quadriceps, hamstrings, gluteus maximus, and gastrocnemius muscles after EIMD. The algometer was used to apply 30 N of force to each muscle belly. The subject gave a verbal rating of pain from zero (no pain) to 10 (most painful) using a categorical pain scale (4). The main drawback of using a category scale is it only allows inferences to be made about the rank order of the different sensations. To overcome these issues, Green et al. (15) developed a scale of sensation magnitude with apparent ratio properties and called it the general labeled magnitude scale (gLMS). The gLMS scale is bounded at the bottom by "no sensation" and at the top by "strongest imaginable sensation." The key feature of the gLMS is that its verbal descriptors (barely noticeable, weak, moderate, strong, and very strong) are placed quasilogarithmically at locations along a straight line that are determined by estimations of their perceptual magnitudes. The gLMS is capable of generating ratio-level data in many sensory modalities (15) and so was employed in this study as an additional measure of muscle soreness.

Hamstring Muscle Length. After modified ACSM guidelines (38) for using a goniometer (Baseline Evaluation Instruments, Fabrication Enterprises, Inc., White Plains, NY, USA), hamstring muscle length was recorded. The fulcrum of the goniometer was placed at the greater trochanter of the femur, with the stabilization arm in line with the axillary fold of the armpit, and the moveable arm in line with the lateral epicondyle of the femur. The nontesting knee was flexed at 90°, whereas the testing knee was extended. An extended knee position was chosen to capture any influence FR may have on hamstring extensibility. Subjects performed active hip flexion until the first sign of resistance or pelvic rotation. Three measurements were taken on the right side, followed by 3 on the left. Measurements were recorded to the nearest degree. According to Sullivan et al. (36), the intraclass correlation value (ICC) for intertester reliability for active hip flexion with an extended knee is 0.93.

Hip Abduction Range of Motion. After the ACSM guidelines (38) for using a goniometer, supine hip abduction was recorded. The fulcrum of the goniometer was placed at the anterior superior iliac spine (ASIS) of 1 hip, with the stabilization arm in line with the contralateral ASIS, and the movement arm down the anterior midline of the femur, using the patella as a reference. The testing leg remained fully extended during the measurement. Active hip abduction was performed until the first sign of resistance, lateral trunk flexion, or external rotation of the hip. Three measurements were taken on the right side, followed by 3 on the left.

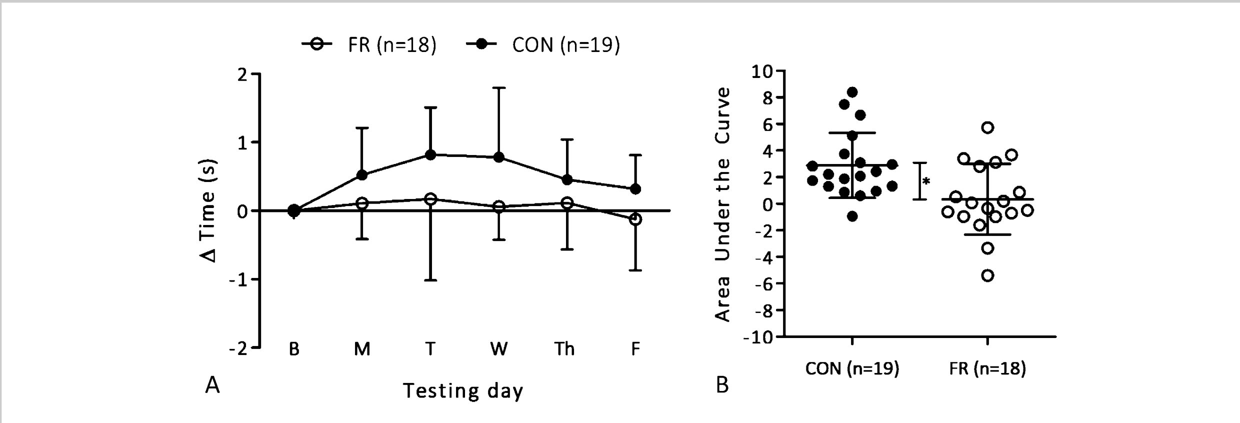

Figure 3. A) Mean change in the time taken to run the agility T-test during the testing week. B) Area under the change (Δ) in agility time (seconds) curve. A 2-tailed Mann-Whitney *U*-test showed a significant difference by condition ($p = 0.0049$) in the area under the Δ time (seconds) agility curve, with foam rolling resulting in less of an impairment to agility time compared with CON. FR = foam rolling; CON = control.

Measurements were recorded to the nearest degree. According to Boone et al. (5), the ICC for inter-rater reliability for active hip abduction is 0.55.

Lower-Body Power. A VJ test was used to assess lower-body power. Vertical jump testing was based on the protocol outlined in *The Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA)* manual (9). A commercial Vertec (Vertec, North Easton, MA, USA) device was used. Without a stutter or preparatory step, subjects were instructed to flex their knees and hips into a partial squat, coming to a full stop at the bottom of the motion to eliminate the stretch reflex. Subjects then jumped up with the dominant arm reaching upward and pushing the highest possible vane. The average of 3 trials was recorded to the nearest 0.5 inches. According to Markovic et al. (24), the ICC for VJ without a countermovement is 0.97.

Agility. The T-test was used to assess subject agility. Four cones were arranged in the shape of a T. Beginning at the bottom of the T, subjects were instructed to sprint 10 yards forward, shuffle 5 yards to the left without any crossing over of the feet or turning of the body, shuffle 10 yards to the right in the same fashion, shuffle 5 yards to the left, and then backpedal 10 yards to the original starting point, touching each cone that formed the T along the way. The average of 2 trials was recorded to the nearest 0.1 second. Disqualification of a trial occurred if the subject failed to touch the base of any cone, crossed 1 foot in front of the other or did not face forward while shuffling (2). According to Raya et al. (31), the ICC for the T-test is 0.98.

Statistical Analyses

Familiarization scores from week 1 were used to calculate baseline data. All week 2 data were then compared to how they changed from baseline (Δ). The area under the curve (AUC) was then calculated for each subject, by condition, by summing the week 2 scores collected from Monday to Friday. All data were then assessed for normality of distribution using the Kolmogorov-Smirnov test. Normally distributed data were compared by condition using a 2-tailed independent *t*-test. If data were not normally distributed, the nonparametric 2-tailed Mann-Whitney *U*-test compared conditions. The alpha level was set at 0.05. Cohen's *d* effect sizes were determined for significant treatment effects using G*Power software and interpreted using the following criteria: >0.20 = small, >0.50 = medium, and >0.80 = large. The minimal detectable change (MDC) was also calculated for significant treatment effects ($MDC = \sqrt{2} \cdot SEM$). All data analysis was completed using GraphPad Prism 5.0 (GraphPad Software, San Diego, CA, USA).

Results

Subject Characteristics

The mean (*SD*) subject baseline scores for all tests are displayed in Table 1. A 2-tailed Mann-Whitney *U*-test showed a significant difference by condition ($p = 0.014$) in the baseline time taken to complete the agility T-test, with CON completing the test in 10.6 ± 1.1 seconds and FR completing the test in 11.6 ± 1.2 seconds. Similarly, a 2-tailed Mann-Whitney *U*-test showed a significant difference by condition ($p = 0.002$) in the baseline vertical jumping height, with CON jumping 24.7 ± 4.4 inches and FR jumping 20.4 ± 3.0 inches. No other significant differences were observed between baseline subject scores or subject characteristics.

Perceptions of Muscle Soreness

Figure 2 displays the mean (*SD*) perception of muscle soreness by condition. No significant differences were observed in the perception of muscle soreness as measured by the gLMS scale between conditions ($p > 0.05$). The mean (*SD*) perception of lower-body muscle soreness measured across both conditions was 21.9 ± 16.0 on Monday, which equated to just above "moderate" on the gLMS scale. This value rose to 40.5 ± 23.1 by Tuesday, equating to a perception of muscle soreness between "strong" and "very strong". Muscles soreness fell to 36.6 ± 24.9 i.e., "strong" on Wednesday, 23.3 ± 17.3 i.e., below "moderate" on Thursday, and 15.6 ± 14.1 i.e., slightly above "weak" by Friday.

No significant differences were observed between conditions in the perception of muscle pain measured in response to 30 N of pressure applied by an algometer applied to the quadriceps, hamstrings, and calf ($p > 0.05$). The mean (*SD*) pain response did not exceed 2.05 ± 2.0 across all conditions and muscle bellies, which equates to a location less than half-way between "no pain" at point 0 and "moderate pain" at point 5 on the visual analog scale 0 to 10.

Range of Motion

Neither hamstring muscle length nor hip abduction differed significantly between conditions ($p > 0.05$). The mean (*SD*) hamstring muscle length and hip abduction, respectively, across both conditions were 84.2 ± 13.9° and 39.6 ± 11.6° on Monday, 82.5 ± 14.1° and 36.0 ± 10.2° on Tuesday, 85.5 ± 11.3°, and 38.0 ± 10.8° on Wednesday, 88.8 ± 10.3° and 40.1 ± 10.3° on Thursday, and 88.2 ± 9.3° and 40.8 ± 10.9°.

Lower-Body Power

Vertical jumping height (inches) did not significantly differ between conditions ($p > 0.05$). The mean (*SD*) VJ height measured across both conditions fell from 22.8 ± 4.1″ at baseline to 20.9 ± 4.3″ on Monday, and 20.7 ± 4.2″ on Tuesday, followed by 21.1 ± 4.1″ on Wednesday, 21.2 ± 4.3″ on Thursday, and 21.2 ± 4.3″ on Friday.

Agility

Figure 3 displays agility scores between FR and CON across the testing week. Agility scores significantly differed by condition ($p \leq 0.05$). Specifically, a 2-tailed Mann-Whitney *U*-test showed a significant difference by condition ($p = 0.0049$) in the area under the Δ time (seconds) agility curve (AUC), with FR resulting in less of an impairment to agility time compared with CON. The AUC was higher in CON (2.88 ± 2.45 seconds) than FR (0.33 ± 2.16 seconds). Mean Monday to Friday values for agility changes from baseline in CON were 0.52, 0.82, 0.78, 0.45, and 0.32 seconds, respectively. Mean Monday to Friday values for agility changes from baseline in FR were 0.11, 0.17, 0.06, 0.12, and −0.13 seconds, respectively. A post hoc analysis of effect size and observed power was calculated using G*Power software. The results indicated that the agility analysis (Power: 0.998, effect size: 1.01) was adequately powered to correctly reject the null hypothesis. Given the effect size, approximately 17 subjects per condition were required to detect a significant difference ($p \leq 0.05$) between conditions, assuming a nonparametric data set analyzed using a 2-tailed Mann-Whitney *U*-test. The MDC was calculated using the individual change in agility scores for the CON condition across the Monday to Friday testing week. Specifically, the MDC for CON, Monday through Friday was 0.44, 0.44, 0.53, 0.41, and 0.37 seconds, respectively. The FR condition surpassed the MDC on Tuesday, Wednesday, and Friday by 0.20, 0.19, and 0.08 seconds, respectively.

Discussion

This study questioned whether FR influences recovery of gross performance measures after EIMD caused by sprinting. To our knowledge, this is the first study to explore the influence of FR on recovery from sprinting-induced muscle damage. The first important finding is that the sprint protocol induced muscle soreness across both conditions. Subjects in both FR and CON experienced "strong" to "very strong" perceptions of muscle soreness as indicated by the gLMS scale (Figure 2). The second important finding is that FR appeared to expedite agility recovery after EIMD caused by the repeated sprinting protocol (Figure 3). The agility T-test time impairment was lower in the FR group compared with CON. Thus, although neither group improved in the T-test after EIMD, the FR group's performance was impaired to a lesser extent. Mean values for agility changes from baseline in CON were 0.52, 0.82, 0.78, 0.45, and 0.32 seconds on the day muscle damage was induced, and on the 4 days following, respectively. Mean values for agility changes from baseline in FR on those days were 0.11, 0.17, 0.06, 0.12, and −0.13 seconds, respectively. These findings indicate that FR may help maintain agility performance after EIMD.

Conversely, VJ height was not different between FR and CON in the present investigation. Previous researchers have reported that both massage and FR are associated with attenuating impairments in jump height or distance after EIMD (22,29). Findings from the present investigation stand in contrast to these previous findings. A notable difference between the methods used during present and previous investigations may shed light on these differing outcomes, and potentially lend insight into the physiological mechanisms underlying the recovery benefits associated with FR. The aforementioned studies both used a traditional countermovement vertical or broad jump. In the present investigation, subjects performed the VJ in line with the Canadian Society for Exercise Physiology standards and paused at the bottom of the movement. This pause increased the amortization phase and may have eliminated subject's ability to fully activate the stretch shortening cycle (SSC). By contrast, rapid changes of direction in the agility T-test necessitated use of the SSC, much like a countermovement jump. That a large effect was observed for agility but not VJ may implicate the removed countermovement, suggesting that FR may benefit athletes who rely heavily on the SSC; however, this requires clarification.

That a recovery modality appears to differentially influence recovery of SSC-based movements compared with non–SSC-based movements is not new. For example, Vieira et al. (40) reported that cold water immersion did not improve recovery in isometric muscle strength but did improve measures of VJ using a countermovement. Thus, the authors suggested that cold water immersion is most beneficial toward SSC performance specifically (40). The prestretch occurring before propulsive muscular action contributes to the enhancement of muscular force production through several neuromuscular mechanisms, including potentiation of contractile machinery and activation of proprioceptive reflexes (8,42). Vieira et al. (40) suggested that immersion in cold water may influence those and other neuromuscular mechanism related to SSC recovery more than attributes contributing to isometric strength. Given the findings of the present investigation, it is reasonable to speculate than FR may also influence neuromuscular aspects relating to the SSC. However, the physiological mechanisms behind this relationship are unclear and warrant further investigation.

The baseline differences between FR and CON in VJ and agility may call into question whether the outcomes observed in this study were due to the FR treatment or inherent between-group differences. Control demonstrated higher baseline scores than those in FR for both VJ (24.7 ± 4.4″ vs. 20.4 ± 3.0″) and agility (10.6 ± 1.1 vs. 11.6 ± 1.2 seconds). Given these findings, it may be reasonable to speculate that FR is more beneficial to lesser athletes. However, this explanation seems unlikely because although CON indeed had greater baseline scores in both VJ and agility, use of the foam roller only resulted in a significant difference in agility. If the observed outcomes were attributable to baseline differences, we would have likely observed a significant difference in both measures. Furthermore, the agility results in this study are consistent with other work in the literature (29), and the VJ results are logically explained by the countermovement's absence.

In the present investigation, FR did not influence hip abduction ROM or hamstring muscle length during recovery from EIMD. A growing body of evidence suggests that FR acutely increases ROM (6,7,11,20,21,25,27,33), without decreasing torque (3,16,23,34,35). The reader should see Cheatham et al. (10) for an expanded discussion on the influence of self-myofascial release on ROM. Although the physiological underpinnings of this effect are unclear, some researchers have suggested that FR influences ROM through both central and localized means (21). Kelly and Beardsley (21) reported that rolling the plantar flexors of 1 leg increased ipsilateral dorsiflexion, along with a smaller increase in contralateral dorsiflexion. This may indicate that ROM increases observed with FR are attributable to a generalized increase in stretch tolerance, in addition to any localized tissue pliability alteration. The joint ROM and muscle length results of the present investigation differ from most of the literature. One possible explanation is that although all major muscle groups in the lower body were subjected to FR, only hip abduction ROM and hamstring muscle length were assessed. Furthermore, only 1 other study (22) to date assessed subjects after EIMD. Exercise-induced muscle damage may alter any influence FR could exert on ROM. Even so, MacDonald et al. (22) reported that FR after EIMD improved acute ROM compared with CON, in contrast with the present investigation. A notable difference in warm-up procedure may explain these contrasting outcomes. The present investigation's warm-up entailed a series of vigorous, dynamic movements as opposed to the 5 minutes of cycling used by Macdonald et al. (22). Foam rolling and dynamic stretching appear to impart similar increases in ROM (3). Thus, any utility FR offers may have already been realized by the experimental and CON groups, by virtue of their matching warm-ups (41).

Jay et al. (19), MacDonald et al. (22), and Pearcey et al. (29) observed that FR after EIMD or DOMS reduced soreness compared with CON. Those results stand in contrast to the present investigation, where no differences between FR and CON were observed. The present investigation used 2 different measures to track changes in muscle soreness across the testing week; a quasilogarithmic scale (gLMS) adapted to measure global perceptions of lower-body muscle soreness on a 0–100 scale and 0–10 pain response to 30 N of pressure applied to the belly of the quadriceps, hamstrings, and calf, respectively. Although a significant difference was not observed between conditions using either measure, the former (gLMS) scale appeared more sensitive to changes in muscle soreness across the testing week. Further research is required to clarify the use of the gLMS as a perceptual marker of muscle damage. Notwithstanding differences in measurement tools, other methodological factors may explain the outcomes observed in this study. Measurements of muscular soreness in the recovery period of this study were always preceded by a warm-up. Jay et al. (19), Macdonald et al. (22), and Pearcey et al. (29) assessed perceptions of muscle soreness on entry to the laboratory, before any activity. The warm-up period used in this study may have served to reduce soreness in both groups and possibly offset any further influence that FR exerted over this dependent variable.

There were several important limitations to this study. First, all subjects were men. Women may respond differently to FR after EIMD. Second, the present findings may be unique to the particular FR protocol used in this investigation. At this time, no standard method, duration, or frequency of FR exists. Third, the findings of the present investigation are limited to recovery from EIMD after a repeated sprint protocol. Individuals experiencing EIMD brought on by other forms of exercise may respond to FR in a different manner. Fourth, the subjects who volunteered for this study were healthy, college-aged men. Other, more specific populations who may or may not benefit from FR after EIMD cannot currently be determined. Fifth, although all major muscle groups of the lower body were subjected to

FR, only hip abduction ROM and hamstring muscle length were assessed. Thus, these findings may be limited to the specific muscle groups tested and the specific measurements used. Finally, neither subjects nor testers were blinded to the condition. The inability to blind those undergoing an FR treatment will likely remain an inherent limitation to research on the topic.

In conclusion, the alternative hypotheses that FR would decrease perceptions of soreness, increase hip abduction ROM, increase hamstring muscle length, and increase VJ compared with CON after EIMD caused by sprinting is not supported, in favor of the null hypothesis that no difference exists between conditions. The data from the present investigation support the alternative hypothesis that agility performance will differ between CON and FR after EIMD caused by sprinting. After EIMD, FR may not offer benefits to ROM or perceptions of muscle soreness beyond what a warm-up and dynamic stretching can provide. However, activities that depend heavily on the SSC may benefit from FR after EIMD. To our knowledge, this is the first study to demonstrate a potential benefit toward agility when recovering from EIMD brought on by high-volume sprinting. Given the popularity of FR as a purported recovery tool, and the preponderance of individuals likely seeking relief from EIMD after high-volume sprinting, this investigation may have implications for practitioners and athletes alike. Furthermore, this study bolsters the case for FR as a general recovery tool. Future studies should investigate the influence of FR on recovery from EIMD brought on by other types of exercise. Another important finding in this study was the possible relationship between FR and the SSC. Future studies should investigate the physiological underpinnings of the relationship between FR and the SSC, along with other recovery methods such as cold water immersion. Such research could potentially shed light on the optimization of recovery methods based on an individual's sport, position, and individual make-up, among other attributes. It is possible that an ideal recovery method for a basketball center may not be the same as that of an offensive lineman in American football, for example. Future studies should also explore the optimal duration, frequency, and method of FR application. As the practice becomes more commonplace, the most beneficial manner in which it can be applied should be explored.

Practical Applications

During recovery from EIMD caused by sprinting, FR may benefit the recovery of athletic attributes related to the SSC, such as agility. Conversely, FR during recovery from EIMD caused by sprinting does not appear to be effective for improving muscular soreness beyond what a vigorous dynamic warm-up can accomplish. The enhanced recovery of agility measures may have significant implications for athletes engaged in sports that require rapid deceleration, acceleration, and change of direction. Practitioners should consider using FR during recovery from demanding exercise when the need for peak agility or change of direction performance is imminent. Furthermore, FR appears to be a beneficial tool for recovery, regardless of the type of exercise performed. Practitioners should encourage the use of foam rollers by athletes recovering from demanding exercise.

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