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Effects of foam rolling for delayed onset muscle soreness on loaded military task performance and perceived recovery

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ABSTRACT

Objective: The purpose of this investigation was to evaluate the effects of foam rolling (FR) and passive recovery (PR) on symptoms of delayed-onset muscle soreness (DOMS) and military-specific performance.

Methods: Twenty men and women (age: 23.6 ± 4.1 years, height: 176.4 ± 5.6 cm, and body mass: 84.7 ± 13.4 kg) completed a DOMS-inducing exercise protocol (DIP), followed by FR or PR. Four loaded military tasks (LMT) were performed 24 h later. Rating of perceived exertion (RPE) was measured during DIP and after each LMT. Rating of muscle pain (RMP) was measured prior to the LMTs and after the recovery protocols. A repeated measure analysis of variance and partial eta squared were used to compare LMT performance across baseline, FR and PR sessions. Friedman tests compared perceptual variables across baseline, FR, and PR. Wilcoxon matched-pairs signed-ranks test evaluated RPE during DIP, post-DIP, and post-recovery RMP between FR and PR.

Results: LMT performance times were significantly faster after FR compared to PR (stair climb: $p = .038$, cover position sprint: $p = .011$, simulated ammunition can carry: $p = .003$, Shuttle Run: $p = .034$). RPE measured during LMTs was similar across all data points. Post-recovery RMP for FR (3.0 (2.3, 4.0)) and PR (4.0 (3.0, 6.0)) were not significantly different.

Conclusion: FR reduced the impact of DOMS on three loaded tactical performance tasks without significant reduction in perceived soreness.

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Introduction

In tactical athlete populations, obtaining and maintaining peak levels of physical fitness are imperative for operational success. To reach the fitness levels required for optimal tactical athlete performance, these athletes are often subjected to high intensity training sessions with high levels of physiological overload. Training movements often consist of running, marching, calisthenics, climbing, hurdling, crawling, jumping, digging, lifting, all while carrying the load of gear and personal protective equipment.¹ Due to the physical demands of training sessions and occupational

tasks, tactical athletes are at a risk for developing delayed onset muscle soreness (DOMS).^{1,2} DOMS is the result of exercise-induced muscle damage and is characterized by soreness and inflammation that may occur immediately after exercise, or develop up to 48 h post-exercise.³ In more extreme cases, the symptoms of DOMS may last several days. Performing unfamiliar movements, movements at high intensities, and movements with emphasized eccentric contractions have been shown to increase the degree of muscle soreness and inflammation.^{4,5}

During Army basic training, the abrupt increase in the physical stress and performance of unfamiliar training movements increases the likelihood of DOMS.¹ The development of DOMS in recruits has important implications in terms of performance and injury risk. Stemming from the intensive physical training requirements of newly recruited soldiers, 25% of men and 50% of women will have to visit an outpatient care unit in the 8 weeks of Army basic training.⁶ The development of DOMS may result in greater reliance

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on synergist muscles to reduce the stress on the affected muscle groups. This may alter joint range of motion, decrease strength and power, change movement techniques, and potentially lead to increased risk of injury.⁷ Considering the injury risk and high frequency of strenuous physical training performed by newly recruited soldiers, it is crucial to incorporate recovery methods to mitigate the symptoms of DOMS and enhance muscular recovery.

Several different treatment methods are used to reduce the symptoms of DOMS. Common recovery interventions include the implementation of active recovery periods, passive recovery periods, foam rolling (FR), massage, stretching, electric stimulation, hot/cold immersion, and wearing a compression garment. Within these common recovery methods, FR stands out as a practical and cost-efficient means of reducing the impact of DOMS on performance and pain.^{8,9,10} FR immediately after a DOMS inducing exercise bout and immediately before a post-recovery performance test have been shown to reduce muscular pain during exercise, minimize decrements in joint range of motion, as well as mitigate decreases in various anaerobic performance tasks.^{8–11}

Current literature provides conflicting conclusions regarding the efficacy of FR on performance in individuals with DOMS.^{8–10,12} However, several investigations have reported drastic improvements in speed, power, strength, range of motion, agility, and overall muscle soreness in physically active male athletes who foam rolled for 20 min after strenuous DOMS inducing exercise.^{8–10} Although FR appears to effectively diminish the symptoms of DOMS in male athletes, the effects of FR on 24-h post-exercise recovery in military populations, or on military specific tasks with external load has yet to be investigated. Therefore, the aim of this investigation was to determine if (1) FR after a DOMS inducing exercise bout mitigates a decline in stair climb (SC), cover-to-cover sprint (CC), simulated ammunition can carry (AC), and shuttle run (SR) performances with external load 24 h post-exercise, and (2) FR improves ratings of muscle pain (RMP) and ratings of perceived exertion (RPE) during these military tasks with external load.

Methods

Study design

This investigation used a randomized crossover design in which each subject completed 2 training sessions and 2 performance testing sessions. Each training session consisted of a resistance training program to induce DOMS, followed by either a FR or passive recovery (PR) treatment. Twenty-four hours following each DOMS inducing training session, subjects began the performance testing session consisting of four load military tasks (LMTs). This approach was used to directly examine the effects of FR on LMTs following an intense resistance training session compared to a control condition consisting of PR.

Subjects

Healthy and physically active men and women ($N = 20$) between the ages of 18–30 years participated in this investigation. Physical activity levels were assessed by a Global Physical Activity Questionnaire.¹³ To be eligible for participation, all participants were required to pass military physical fitness requirements and have at least 1 year of resistance training experience.¹⁴ All participants were free from injury and had no health complications assessed by the American College of Sports Medicine (ACSM) health history questionnaire.¹⁵ All participants were asked to refrain from using pain-relieving and anti-inflammatory medications or performing any activities that could impact the symptoms of DOMS throughout the duration of the study. The study was approved by

the University's Institutional Review Board and the subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document that outlined all study requirements.

Descriptive characteristic assessment and one-repetition max estimation

Participants reported to the laboratory on 6 separate occasions. On the first visit, anthropometric and body composition assessments were conducted, and back squat 1-repetition max (1RM) was estimated. Body mass was measured to the nearest 0.1 kg on a digital scale (SOLO, Detecto, Webb City, MO), height was assessed using a standard stadiometer and rounded to the nearest 0.1 cm, and body composition was measured using a 3-site skinfold procedure (male: chest, abdomen, thigh; female: triceps, suprailiac, thigh) with a Lange skinfold caliper (Cambridge, MD, USA). Participants then performed a series of back squat submaximal repetitions to failure, which was then used to extrapolate their predicted 1RM.¹⁶

After the multiple RM testing, participants rested for 15 min before performing a military physical fitness tests for basic training. The U.S. Army basic training physical fitness test is conducted to evaluate if individuals have met the minimum qualifications to graduate boot camp. The army physical fitness test consists of the maximum number of push-ups and sit-ups completed in 2 min, and a 2-mile run.¹⁷ The push-ups and sit-ups were performed on a mat in a controlled laboratory environment. The 2-mile run was performed on an outdoor track, while using a stopwatch to record completion time. If the minimum criteria were not reached, participants were excluded from the study.¹⁷

Approximately 20 min after the physical fitness test, participants completed a familiarization session. During the familiarization session, participants were encouraged to practice all performance tasks as many times as they desired. Participants reported back 24 h later to perform four LMTs that served as the baseline measurements. The remaining visits consisted of two training sessions, each followed by performance testing session 24 h later. During training sessions, participants performed a DOMS-inducing resistance training session followed by 20 min of either FR or PR. The training sessions were separated by 5 days to allow sufficient recovery and the order of post-training treatment (FR or PR) was counterbalanced. Participants were asked to replicate their diet for each training session, 24 h prior to and 24 h after the training session. Each participant performed their training sessions on the same day and time each week.

Loaded military tasks (LMT)

Four LMTs adapted from the methodology of Lowe and colleagues (2016) were used in this investigation.¹⁸ Each task was performed while participants wore a 12-kg weighted vest (Short Style, MIR, San Jose, CA) to simulate the weight carried by a soldier during combat. A 4-min rest period separated each task. All four tasks were timed using a photocell timing gate system (Brower Timing System, Draper, Utah) and each participant was given three attempts per task. The first task was a timed SC during which participants sprinted up three flights of stairs as quickly as possible. The structure of the stairs consisted of three turning platforms and a total of 52 steps. A tennis ball was carried in each hand to prevent the use of railings while climbing, such as when carrying a firearm or other equipment carried by soldiers. The second task was a timed CC that mimicked running to a cover point to shield from enemy fire. Four cones were set in a zig-zag formation (right, left, right line of movement), with 10.97 m between each cone.

Participants sprinted to the first cone and touched one knee to a pad on the floor before sprinting to the next cover point. The third task was a timed simulated AC. To resemble two ammunition cans, participants carried one 13.6-kg kettle bell in each hand. Participants carried the kettle bells and sprinted a total distance of 45.72 m. The fourth task was a 182.88 m (200-yard) SR that was performed on a wooden gymnasium floor. Each participant sprinted back and forth between two sets of cones placed 22.86 m apart a total of eight times.

DOMS-inducing exercise protocol (DIP)

Participants reported to the laboratory in a 2-h postprandial state. Participants performed a general warm-up, pedaling on a stationary cycle ergometer with a fixed workload of 1 kp resistance at 70 RPM for 5 min.⁸ Following the warm-up, participants completed a DIP. During each DIP, participants performed 2 sets of 5 repetitions barbell back squats using a load equivalent to 50% of their previously established 1RM.⁸ To induce DOMS, each participant performed 10 sets of 10 repetitions of barbell back squats at 60% of their estimated 1RM with 2-min rest periods separating each set. Squat depth was standardized by using stacked 5-cm spacers to ensure the femur was parallel to the floor during the amortization phase of the squat.⁹ Using a metronome to standardize cadence of each repetition, the squat tempo consisted of a 4-s eccentric phase, 1-s pause at the bottom, 2-s concentric phase, and a 1-s pause at the top.⁹

Recovery methods

The two recovery protocols were performed immediately after each DIP in a counterbalanced order. Recovery protocols included: 1) FR of the lower limbs and 2) PR consisting of sitting. The FR protocol used in this investigation was based on the methodology of Pearcey and colleagues (2015).⁹ The FR instrument used was a hollow polyvinyl chloride pipe with a diameter of 10.16 cm encased by 1-cm thick neoprene foam. Participants began by placing the foam roller at the proximal portion of the muscle and exerting as much body mass as tolerable onto the foam roller. A cadence was set to 50 beats per minute to control a consistent back and forth motion. FR was performed for 45 s, followed by a 15-s rest for each muscle group and repeated twice. Muscles that were targeted were performed in the following order: 1) gluteals, 2) hamstrings, 3) iliotibial band, 4) quadriceps, and 5) adductors. Total FR time, including rest, was 20 min. PR consisted of resting in a chair for 20 min while consuming water ad libitum.

Perceptual measurements

RPE were documented after every set in the exercise protocol and after the performance of each LMT. RPE was measured using a 10-point scale (Young Enterprises Incorporated, Lansing, Kansas). RMP were documented following each DIP, recovery method, and prior to performing each LMT. The RMP was measured using a 11-point scale, ranging from “no pain” (0 points) to “worst possible pain” (10 points).¹⁹

Statistical analysis

Data were analyzed using the IBM Statistical software package (Version 25 (IBM Corp., Armonk, NY)). LMT statistics are reported as means \pm SD and perceptual statistics are reported as median and 25th and 75th percentiles. Repeated measures analysis of variance (RMANOVA) was used to compare LMT results between baseline, FR, and PR. Least significant difference pairwise comparisons were

used for post-hoc analyses. Partial Eta squared were also calculated to compare the FR and PR methods. Average RPE scores assessed during each LMT and RMP measured pre-LMT testing were compared using a Friedman test. If warranted, a post-hoc analysis implementing the Wilcoxon signed-ranks test was used. Wilcoxon matched-pairs signed-ranks test was also used to compare training session RPE and post-training session and post-recovery RMP between FR and PR. Statistical significance was considered when $p \leq .05$.

Results

Initially, 21 participants were recruited for the study, however, one participant's data were excluded due to noncompliance with the investigators' pre-testing instructions. Therefore, data of 20 participants were used for statistical analyses. Descriptive characteristics of participants, 1RM data, and physical fitness testing performance data are presented in Table 1.

Comparisons of LMT performance between conditions can be found in Table 2. Mean CC, AC, and SR times were similar between baseline and FR conditions, while PR times were significantly slower than baseline for AC and SR. Interestingly, mean SR time for the FR condition was significantly faster than baseline. No significant differences in SC or CC times were found between baseline and FR condition times. Peak AC and SR times were significantly slower compared to baseline.

Perceptual variable data are presented in Table 3. No significant differences in RPE during LMT were found between recovery methods. Additionally, RMP measured pre-LMT and post-DIP were not different between recovery methods.

Discussion

In the current investigation, the DOMS-inducing exercise session impaired performance on three of the four LMTs 24 h later regardless of the post-exercise recovery method used. The 20-min FR treatment performed immediately after a DOMS-inducing exercise session effectively mitigated the negative impact of DOMS on military task performances while wearing a 12 kg external load in comparison to a PR. Surprisingly, FR had no significant impact on RMP or RPE at any time point in comparison to baseline or PR conditions. These findings suggest that FR can reduce the impact of DOMS on military performances, and that the mitigation of these performance decrements may be independent of changes in muscle pain or perceived exertion.

For three of the four LMTs included in the current study, participants' performances were 3.2–6.1% slower after the DOMS-inducing exercise session with PR in comparison to baseline times. For those same LMTs, times for the FR condition were just 0.9–1.6% slower than baseline. Similar impairments in sprint, jump, and upper limb performance variables have been reported in the literature after DOMS was induced in samples of physically active

Table 1
Participants' descriptive statistics (mean \pm SD).

Variable	Full sample (N = 20)
Age (years)	23.6 \pm 4.1
Height (cm)	176.4 \pm 5.6
Body mass (kg)	84.7 \pm 13.4
Body fat (%)	17.3 \pm 9.2
1 RM back squat (kg)	132.5 \pm 45.1
Sit-ups	54.6 \pm 10.6
Push-ups	48.6 \pm 23.5
2-mile run (s)	900.3 \pm 102.0

Table 2
Military performance task times (s) during baseline, foam rolling, and passive recovery trials. (mean ± SD).

Task	Recovery Method			p	η ² _{partial}	
	Baseline	FR	PR			
SC	Peak	13.7 ± 3.4	13.3 ± 3.4	13.5 ± 3.7	.293	.062
	Mean	14.7 ± 4.1	13.8 ± 3.8*	14.2 ± 4.4	.038	.160
CC	Peak	10.8 ± 1.8	10.8 ± 1.6	11.1 ± 1.9	.118	.109
	Mean	11.2 ± 2.1	11.1 ± 1.6	11.6 ± 2.1 [†]	.047	.153
AC	Peak	12.7 ± 3.7	12.8 ± 3.0	13.4 ± 3.6*	.011	.224
	Mean	13.1 ± 3.7	13.3 ± 3.2	13.9 ± 3.6* [†]	.003	.270
SR	Peak	49.0 ± 7.5	50.3 ± 7.7	50.9 ± 8.4*	.036	.162
	Mean	50.6 ± 8.2	51.4 ± 7.5	52.2 ± 8.9*	.034	.164

Note: AC: simulated ammunition can carry; CC: cover-to-cover sprint; FR: foam roll; PR: passive recovery; SC: stair climb; SR: shuttle run.

* Indicates different from baseline.

[†] indicates different from FR.

Table 3
Perceptual measurements at baseline, foam roll and passive recovery methods (N = 20; median, 25th, and 75th percentile).

Variable		Recovery Method			p
		Baseline	FR	PR	
RPE	SC	3.8 (3.3, 4.7)	4.2 (2.8, 5.3)	3.8 (3.1, 6.5)	.211
	CC	3.2 (2.7, 3.7)	3.0 (2.4, 3.6)	3.0 (2.7, 3.3)	.104
	AC	3.3 (2.7, 4.3)	4.0 (3.0, 4.9)	3.8 (2.8, 5.3)	.164
	SR	7.0 (5.4, 7.6)	6.0 (5.0, 7.3)	5.8 (5.0, 7.3)	.329
	DIP	–	6.9 (5.5, 8.0)	7.4 (6.4, 8.1)	.100
RMP	Pre-LMT	2.0 (0.0, 4.0)	3.0 (1.3, 4.0)	5.0 (2.3, 7.0)	.086
	Post-DIP	–	5.0 (3.3, 6.8)	5.0 (2.3, 6.8)	.979
	Post-treatment	–	3.0 (2.3, 4.0)	4.0 (3.0, 6.0)	.057

AC: simulated ammunition can carry; CC: cover-to-cover position sprint; DIP: DOMS inducing exercise protocol; FR: foam roll; LMT: loaded military performance tasks; PR: passive recovery; RMP: ratings of muscle pain; RPE: ratings of perceived exertion; SC: stair climb; SR: shuttle run.

males.^{20,21} Although the exact mechanisms responsible for the negative impact of DOMS on performance is unclear and is likely multifactorial, the diminished performance of participants in this study could be attributed to damage to contractile and connective tissues within sarcomeres, muscular fatigue and loss of strength, and decreased range of motion due to inflammation.^{21,22} These physiological stressors are the result of high physical demands and/or overuse, which are commonplace during military training and can lead to altered balance, joint proprioception, functional joint stability, and compensatory movement patterns.^{23–25} The collective structural damage to muscle/connective tissues and subsequent altered movement patterns likely increase the risk of incurring musculoskeletal injury in military populations, which imposes significant burdens in terms of military readiness and treatment costs.^{25–27}

The results of this investigation suggest that FR for 20 min immediately after an intense exercise session can effectively alleviate decrements in SC, CC, simulated AC, and SR performances in comparison to a PR in adults with physical fitness characteristics similar to those of Army recruits. These findings are in agreement with those of Pearcey et al. (2015) and MacDonald et al. (2014), who found that FR improved 30-m sprint, broad jump distance, T-test performances, vertical jump height, and range of motion in healthy and physically active male participants after a DOMS-inducing resistance training session.^{8,9} In each of these studies, the authors identified the possibility that the lessened drop in performance observed after FR conditions may be partially mediated by a decrease in muscle tenderness.^{8,9} However, results of our investigation do not support this theory. FR had no significant impact on

RMP after DOMS-inducing exercise sessions, prior to performance testing, and after completion of recovery methods when compared to baseline or PR conditions. Similarly, RPE were not significantly different for any LMTs between baseline, FR, or PR conditions.

Several physiological mechanisms by which FR enhances recovery from DOMS have been offered in the literature. While the mechanisms responsible for this enhancement are controversial, increases in muscle blood flow and the stimulation of Golgi tendon organs and the subsequent relaxation of muscle fibers and fascia are commonly accepted explanations.^{28–31} This increase in blood flow may lead to a reduction in tissue edema and increased rate of tissue repair.³² Additionally, FR could elicit beneficial biochemical changes such as increased transport of neutrophils and prostaglandins to the site of damaged tissue and decrease cytokine activity, indicating a lessened inflammatory response.^{25,33} These collective physiological and biochemical responses to FR have been attributed to a simultaneous improvement in performance and lessened muscular pain.^{8,9} However, FR improved LMT performance with no change in muscle pain or perceived exertion in the current study. This suggests that the observed improvements in performance after FR compared to PR were due to physiological responses to the treatment rather than psychological and perceptual changes.

This investigation may be the first to report the impact of DOMS on military-specific performances while wearing an external load; as well as the effects of FR for diminishing the negative impact of DOMS on these performances. Additionally, our findings suggest that the benefit of FR for mitigating performance decrements due to DOMS can occur without changes in perceived difficulty or pain. These findings are of considerable practical importance for military populations who are often subjected to strenuous daily training or missions that may increase the likelihood of DOMS and musculoskeletal injury. For these individuals, FR devices are affordable, portable, and simple tools that can enhance recovery and significantly improve military specific performance. The implementation of FR protocols in the military paradigm could increase military readiness and effectiveness, as well as decrease the risk of overuse and musculoskeletal injuries.

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Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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