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Effect of foam rolling on delayed onset muscle soreness (DOMS) with pain scores and power performance in varsity rugby players

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Abstract
Foam rolling (RF) has been recently proposed as a recovery strategy to reduce Delayed Onset Muscle Soreness (DOMS). It consists of a mechanical technique that mimics manual massage by using a dense FR to apply pressure on soft tissues. Previous findings observed a Pain Pressure Threshold (PPT) increase in both contralateral and ipsilateral limbs after rolling the ipsilateral plantar flexors, a tendency for a reduction in perceived soreness 10 minutes after a FR intervention. These studies suggest that the central nervous system may mediate recovery (e.g., perceived pain) processes. The main objective of current study was to determine whether the foam rolling had any effect on DOMS and pain scale. Twenty male rugby players (age: 20.7 ± 1.5 years) from University Malaya Rugby team who had no history of quadriceps injuries in the past 6 months were recruited for this study. Written informed consent was obtained from all the participants, repeated-measures design was used to examine the effects of foam rolling on the quadriceps: (1) numerical rating scale of the quadriceps pain score, (2) power (vertical jump height). All participants were divided into two groups that will undergo DOMS protocol (10 sets x 10 repetition of barbell back squats with 60% of 1RM) and a control group. Variables were measured at baseline, 24h post-DOMS protocol, 48h, and 72h. FR intervention was applied right after testing session, 24, 48 and 72 hours post-testing, consisting of rolling the quadriceps, adductors, hamstrings, iliotibial band, and gluteal muscles for 1 set of 45 seconds with 15 seconds rest for each muscle, repeating the protocol one time. Results of this study found that FR resulted in reduced pain score and increased power at various time points after exercise compared with the control condition. This results provide strong evidence that foam rolling can reduce DOMS and the associated in power output. Current findings shown that FR can improve physical performance, and alter the pain perception. This results supported previous studies that FR prophylactic effect after DOMS is due to a blood flow increase in the damaged tissue, and thus enhancing blood lactate removal, reducing tissue edema, and promoting higher and faster oxygen delivery to the muscle.

Keywords: foam rolling, delayed on-set muscle soreness (DOMS), vertical jump performance, pain scales

Introduction

The speed of physical recovery after delayed onset muscle soreness (DOMS) is a crucial aspect of physical performance optimization and training methodology. It has been reported that DOMS decreases muscle maximal force production, muscle rate of force development, ability to sustain submaximal isometric contractions (Ye *et al*., 2015) [23].

In addition, among other physiological effects, it is reported that DOMS increases muscle tenderness and swelling (Cleak & Eston, 1992) [8], joint resistance to stretch (i.e., due to tissues passive tension increase) (Whitehead, Weerakkody, Gregory, Morgan, & Proske, 2001) [22], edema (Lacourpaille *et al*., 2014) [14], blood creatine kinase (Nosaka & Clarkson, 1996b) [17] and blood myoglobin (Davies *et al*., 2008) [10]. These effects peak at 24-72 hours following exercise-induced muscle damage (Cheung, Hume, & Maxwell, 2003) [7], and are thought to be restored to baseline at a faster rate by different physical approaches like massage, cryotherapy, static stretching, and low-intensity exercise (Torres *et al*., 2012) [20]. However, a recent systematic review has reported a lack of effectiveness for most of these methods, whereas massage proved to be slightly effective in the relief of DOMS symptoms (Torres *et al*., 2012) [20].

Foam rolling has been recently proposed as a recovery strategy to reduce DOMS symptoms by using a foam roller (FR: Cheatham *et al*., 2015) [6]. It consists of a mechanical technique that mimics manual massage by using a dense FR to apply pressure on soft tissues.

It has been demonstrated that FR does attenuate decrements in lower extremity muscle performance by improving both static-passive and static-dynamic hip flexion ROM, muscle activation, vertical jump height, and reducing perceived pain in the subsequent days after DOMS (Pearcey *et al*., 2015) [18].

It has been suggested that the FR prophylactic effect after DOMS is due to a blood flow increase in the damaged tissue, and thus enhancing blood lactate removal, reducing tissue edema, and promoting higher and faster oxygen delivery to the muscle (Cheatham *et al*., 2015) [6].

Aboodarda, Spence, & Button (2015) [1] observed a pain pressure threshold increase in both contralateral and ipsilateral limbs after rolling the ipsilateral plantar flexors. Similarly, Jay *et al*. (2014) [13] observed a tendency for a reduction in perceived soreness 10 minutes after an RM intervention. These studies suggest that the central nervous system may mediate recovery (e.g., perceived pain) processes. However, it is unknown if the RM contralateral effects occur following a DOMS stimulus.

Objective

The main objectives of this study were to determine the effectiveness of FR on DOMS with numerical pain rating scales (NRS) and power performance after the DOMS protocol.

Based on previous literature, we hypothesized that FR will induce reduction of pain effects in numerical pain rating scales (NRS). In both experiments, DOMS was induced unilaterally to the quadriceps muscle in two interventions: with and without the FR. In test 1, FR variables were assessed immediately after tests, 24h post, 48h post, and 72h after DOMS. While in experiment 2, without FR variables were assessed immediately after, 24h post, 48h post, and 72h after DOMS protocol.

Methods

Participants

Twenty male rugby players (Age: 20.7 ± 1.5 years; body mass: 74.3 ±10.88 kg; height: 167.4 ± 14.4cm; body fat: 19.3 ± 8.2%) volunteered for the experiment 1 and 2. All participants were University Malaya Rugby players, who had no history of quadriceps or lower limb injuries in the past 6 months. Written informed consent was obtained from all the participants.

Procedures

Repeated-measures design was used to examine the effects of foam rolling the quadriceps: (1) numerical rating scale of the quadriceps pain score, (2) power (vertical jump height), All participants were divided into two groups that underwent DOMS protocol (10 sets x 10 repetition of barbell back squats with 60% of 1RM) in 2 experimental conditions: without foam rolling massage and evaluated their NFR and with FR. Variables (NFR and Power performance) were measured at baseline, 24h post-DOMS protocol, 48h, and 72h. FR intervention was applied right after testing session, 24, 48 and 72 hours post-testing, consisting of rolling the quadriceps, adductors, hamstrings, iliotibial band, and gluteal muscles for 1 set of 45 seconds with 15 seconds rest for each muscle. Subjects were asked to apply their own bodyweight onto the foam roller.

Exercise (DOMS Protocol)

The squat technique was adopted from the National Strength and Conditioning Association. The tempo for each repetition was a 4-second eccentric contraction, no pause, and a 1-second concentric contraction (Baechle & Earle, 2008) [3]. Participants rested for 2 minutes between sets. Total squat time was 8 minutes, 20 seconds, and rest time was 18 minutes. We emphasized eccentric contractions because repetitive eccentric exercise has been shown to result in more DOMS than conventional weight training that emphasizes concentric contractions. (Cheung, Hume, & Maxwell, 2003) [7].

Foam Rolling Participants used a foam roller that had a 15cm diameter and 30cm length. They were instructed to begin with the foam roller at the most distal portion of the muscle. We instructed them to place as much body mass as tolerable on the foam roller at all times and to roll their body mass back and forth along with the roller as smoothly as possible at a cadence of 50 beats per minute (i.e., 1 rolling motion per 1.2 seconds). Foam rolling was performed for 4 sets of 45 seconds and followed by a 15-second rest. This was accomplished for each muscle group in each lower extremity and repeated once. Total foam-rolling time, including rest, was 20 minutes. Foam rolling was performed directly after the DOMS protocol was done sessions 1, session 2 (24 hours post-DOMS protocol), and session 3 (48 hours post-DOMS protocol) and session 4 (72 hours post-DOMS protocol). Whereas DOMS was not immediately evident after testing session 1, we chose this time to foam roll because massage has been shown to enhance blood lactate removal and tissue healing (Weerapong, Hume & Kolt, 2005) [21]. Furthermore, participants foam rolled after testing sessions 2 and 3 because of the intensity of DOMS increases within the first 24 hours and peaks around 48 hours' post-exercise (Amstrong, 1984) [2]. We chose these time points because no empirical evidence recommending the most optimal duration and timing of post-exercise foam rolling was available. The foam-rolling technique for each muscle and the order in which each muscle was foam rolled follows.

Quadriceps

Starting in a prone position with the roller approximately 3 in (7.62 cm) inferior to the anterior superior iliac spine, participants crossed 1 leg over the other (Figure 1A). They rolled down to a position superior to the patellar tendon and back using their elbows to guide movement.

Adductors

Starting in a prone position with the hip flexed and externally rotated, participants positioned themselves on the roller with the proximal portion of the adductor group just inferior to the inguinal area (Figure 1B). They rolled down to a position superior to the medial condyle and back by shifting their body mass from side to side.

Hamstrings

Starting just inferior to the gluteal fold with the hips unsupported, participants crossed 1 foot over the other (Figure 1C). Their body mass was supported and maneuvered by the hands, which were posterior to the body. They rolled from the starting position down to the superior portion of the popliteal fossa and back.

Iliotibial Band

Starting in a side-lying position just inferior to the greater trochanter, participants placed the free lower extremity anterior to the supported extremity (Figure 1D). They rolled down to just superior to the lateral condyle and back with the free foot guiding the movement.

Gluteal

Starting just inferior to the posterior portion of the iliac crest on the lateral portion of the gluteal region, participants crossed 1 foot over the opposite knee in a figure-4 formation while supporting the body on 1 hand (Figure 1E). Using the support hand, they rolled down to a position superior to the gluteal fold and back.

Fig 1: A participant demonstrates the 5 muscle groups foam rolled and the technique used for each muscle group. Foam rolling consisted of 45 seconds of rolling for each muscle in the left lower extremity, 15 seconds of rest, 45 seconds on the right lower extremity, and 15 seconds of rest for all muscles in the following order: A, quadriceps, B, adductors, C, hamstrings, D, iliotibial band, and E, gluteal. Total foam-rolling time was 20 minutes (15 minutes of rolling and 5 minutes of rest).

Numerical Rating Scale

The numerical rating scale is used to assess quadriceps pain post DOMS protocol. We measured the NRS for each participant's quadriceps at 24, 48, and 72 hours' post-test. Participants were instructed to choose between 0 to 10 if as schedule below:

Participants were instructed to choose between 0 to 10 if as schedule below:

Rating	Pain Level
0	No Pain
1–3	Mild Pain
4–6	Moderate Pain
7–10	Severe Pain

Power Performance

A standing vertical jump (Vertec) was used to measure dynamic power. Participants were instructed to stand with their feet 1 shoulder-width apart, jump above as far as they could, and land in a controlled manner on 2 feet without taking a step to maintain balance. We measured the jump from the fingertips reaches of the starting position to the Vertec, and this is called the standing reach height. The athlete then stands below the Vertec and leaps vertically as high as possible using both arms and legs to assist in projecting the body upwards. Attempt to touch the Vertec at the highest point of the jump. The difference in distance between the standing reach height and the jump height is the score. The best of three attempts is recorded. Each participant was separated by 4 minutes of rest.

Results

A one-way repeated-measured analysis of variance (ANOVA) was conducted to evaluate the NRS scores post-DOMS protocol 24, 48, and 72 hours in rugby male varsity players (N=20). The results of ANOVA indicate that there was a significant NRS effect, Wilks' Lambda = .03, $F(2, 17) = 298.6$, $p<0.05$, partial $\eta 2 = .97$.

Normality checks were carried out on the residuals, which were approximately normally distributed. A repeated-measures ANOVA with a Sphericity Assumed correction showed that mean NRS score differed significantly between time points [F (2, 112.72) = 275.42, *p*<0.001]. Post hoc tests using the Bonferroni correction revealed that NRS score reduced by an average of 1.1point between 24hours measurement and 48 hours' measurement interval (*p*<0.001), reduced by an average of 4.55point between 24 hours and 72 hours' measurement interval (*p*<0.001) and then reduced by an average 3.45 point between 48 hours and 72 hours' measurement interval.

A one-way repeated-measured analysis of variance (ANOVA) was conducted to evaluate the null hypothesis that there is no difference in Vertec Jump Test score post-DOMS protocol 24, 48, and 72 hours in male varsity rugby player (N=20). The results of ANOVA indicate that there was a significant Vertec (Power) performance effect, Wilks' Lambda = .06, F (2, 17) = 131.9, *p*<0.05, partial η2 = .94.

Normality checks were carried out on the residuals, which were approximately normally distributed. A repeated-measures ANOVA with a Sphericity Assumed correction showed that mean Vertec Jump Test score differed significantly between time points [F(2, 176.15) = 186.512, *p*<0.001]. Post hoc tests using the Bonferroni correction revealed that Vertec Jump Test score improved by an average of 1.6cm between 24 hours' measurement and 48 hours' measurement interval (*p*<0.001), improved by an average of 5.750 between 24 hours and 72 hours' measurement interval (*p*<0.001) and then improved by an average 4.150 point between 48 hours and 72 hours' measurement interval.

Discussion

After intense bouts of exercise, many individuals use foam rolling to aid in recovery from muscular fatigue and soreness. We examined the use of foam rolling after a DOMS-inducing 10 sets x 10 repetition of barbell back squats with 60% of 1RM protocol. Main findings of current were that foam rolling enhanced recovery from DOMS and increased physical performance after the DOMS protocol. More specifically, foam rolling resulted in reduced NRS pain score and increased power at various time points after exercise compared with the without FR condition. This results provide strong evidence that foam rolling can reduce DOMS which associated with decrements in performance.

Delayed-onset muscle soreness is characterized by variable amounts of muscle tenderness, stiffness, and pain that can fluctuate from slight muscle stiffness on palpation to severe debilitation of athletic performance (Gulick, 1996) [11]. The DOMS protocol (10 sets x 10 repetition of barbell back squats with 60% of 1RM), which included 1-second concentric and 4-second eccentric contractions, promoted the development of severe DOMS and substantially decreased physical performance. Many emphasizing eccentric exercise have resulted in muscular pain along with decrements in performance. In our study, NRS pain thresholds were decreased at all-time points post-exercise, indicating an increase in muscle tenderness.

Another important point is that we also observed increments in performance measures for Vertec Jumps for FR subject test throughout the 72 hours' post-exercise: jump height increased 28%, 0.3%, power decreased in the NFR group 48 hours post-DOMS protocol show sign that participant is still affected by DOMS. The improvement in performance may be due to a combination of several factors, including (1) physiologic damage to sarcomeres during intense exercises, such as tearing of Z-lines (Nguyen, Brown & Coburn, 2009) a reduction in strength due to acute muscular fatigue (Sakamoto *et al*. 2010); (3) decreased range of motion; (4) increased inflammation; and (5) trepidation resulting from the pain of movement (Bottas *et al*., 2009) [4].

The increment of power performance differed between the foam-rolling group and the group without FR. Similar to the effect of post-exercise massage, foam rolling appears to aid in the recovery of muscle tenderness associated with DOMS. Similar to other research (MacDonald *et al*., 2014) [15], we found that a 20-minute foam-rolling session caused participants to experience substantially less muscle tenderness. Researchers have shown that massage may reduce the pain associated with DOMS.

Foam rolling positively affected both NRS and power performances at 48 and 72 hours' post-exercise. Vertical jump movements involve the acceleration of the body in a single direction. Various postulated mechanisms may explain why foam rolling enhanced the recovery from muscle tenderness and associated dynamic performance measures throughout the 72 hours' post-exercise. The most common mechanisms are decreased edema, enhanced blood lactate removal, and enhanced tissue healing (Baechle & Earle, 2008) [3], which are mainly due to the increase in muscular blood flow (Cafarelli & Flint, 1992) [5]. Increased blood flow hinders the margination of neutrophils and reduces prostaglandin production, subsequently decreasing inflammation (Hovind & Nielsen, 1974) [12]. Massage-induced muscular blood flow also increases oxygen delivery, which encourages mitochondrial resynthesize of adenosine triphosphate and the active transport of calcium back into the sarcoplasmic reticulum (Armstrong, 1984) [2]

However, considering that the roles of lactate and adenosine triphosphate depletion in fatigue are widely disputed, these explanations seem unlikely. Regardless, the action of foam rolling, similar to massage, could increase muscular blood flow and result in enhanced recovery from DOMS in other ways. Massage-related biochemical changes include (1) increased circulating neutrophil levels (Smith *et al*., 1994) [19].; (2) smaller increases in post-exercise plasma creatine kinase (Smith *et al*., 1994) [19]; (3) activated mechanosensory sensors that signal transcription of COX7B and ND1, indicating that new mitochondria are being formed and presumably accelerating the healing of the muscle (Crane *et al*., 2012) [9]; and (4) less active heat-shock proteins and immune cytokines, reflecting less cellular stress and inflammation (Crane *et al*., 2012) [9].

These biochemical changes were due to massage that applied constant pressure to the muscle. Perhaps the constant pressure on the muscle from foam rolling resulted in biochemical changes similar to those reported earlier. Foam rolling substantially reduced the negative effect of DOMS on dynamic movements, which incorporate power. The foam-rolling–induced enhancement of recovery after the exercise protocol may have been due to a reduction in reduced pain, increased voluntary activation, (MacDonald *et al*. 2014) [15] and various other aforementioned mechanisms that were characterized by massage research.

The time chosen for participants to foam roll was based on current clinical recommendations that 20 minutes of foam rolling is a substantial amount of time. Researchers should examine the frequency, intensity (amount of pressure placed on the foam roller), time (immediately post-exercise versus other time points), and type (sweeping pressure versus undulations) of foam rolling that optimize recovery after intense physical performance events.

Athletes commonly must train and compete during consecutive days despite discomfort and pain they may have sustained from the previous exercise. At times of severe DOMS, athletes can experience decrements in physical performance up to and beyond 72 hours' post-exercise. To combat the adverse effects of DOMS, a 20-minute bout of foam rolling on a high-density roller immediately post-exercise and every 24 hours thereafter may reduce the likelihood of muscle tenderness and decrements in dynamic muscle power. Just three 5-minute bouts (15 minutes total plus 5-minute rest) of foam rolling can substantially enhance recovery after DOMS and alleviate muscle tenderness. This form of self-induced massage could benefit athletes seeking a recovery modality that is relatively affordable, easy to perform, and time efficient and that enhances muscular recovery.

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