TOPICS IN EXERCISE SCIENCE AND KINESIOLOGY

Expedited Article

The Effect of an Acute Bout of Foam Rolling on Running Economy

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ABSTRACT

Topics in Exercise Science and Kinesiology Volume 2: Issue 1, Article 4, 2021. This study examined the impact of pre-exercise foam rolling on running economy at 5 km race pace. Sixteen trained distance runners (31.5±12.2 yr; $\dot{V}O_{2max}$ 53.6±11.0) volunteered for the study. Participants completed two treadmill runs at self-selected 5 km race pace; one session with the use of pre-exercise foam rolling and the other with a controlled rest period prior to the run. Running economy was improved during the session with pre-exercise foam rolling applied ($t(15)=2.48$, $p=.026$, $d=.62$). These findings provide evidence for the acute effects of pre-run foam rolling on a parameter of running performance. These results also support the use of foam rolling as a warm-up strategy prior to a high intensity run. Future studies are needed to determine the underlying mechanisms behind the observed improvement.

KEY WORDS: Self-myofascial release, pre-exercise, running performance

INTRODUCTION

The use of foam rolling as a form of self-myofascial release has become popular due to its affordability and ease of use. According to a recent survey, a foam roller is the most commonly used and recommended roller massage device by physical therapists, athletic trainers, and fitness professionals, yet 88% believe there is a gap in the research (7). Foam rolling is a common practice for endurance runners before and after running. A recent survey including distance runners of various competitive levels found that 54.7% use foam rolling as a strategy during their training (4). Despite its popularity, the evidence surrounding foam rolling and its effect on endurance running performance parameters is limited.

Fascia plays a large role in musculoskeletal dynamics. Healthy fascia leads to better quality of movement, while restricted fascia becomes a site of tension, diminishing functional movement capacity (34). The material properties of fascia are influenced by mechanical pressure and temperature (2, 34). Prior literature suggests that the friction which is generated by self-massage tools such as foam rolling alters fascia's material properties by increasing blood flow and intramuscular temperature in the affected area (20, 23). Physiological evidence shows that an acute bout of foam rolling influences the sliding properties and mobility of fascial layers, improves vascular endothelial function, reduces arterial stiffness, and increases arterial blood flow (15, 18, 27, 32). Practically, foam rolling increases flexibility and range of motion, as well as reduces perceptions of muscle fatigue and soreness (13, 14, 20, 35, 36, 40).

Foam rolling is an appealing warmup strategy for sport performance due to studies documenting increased blood flow to muscle, increased muscular temperature, and improved range of motion following foam rolling. Recent research promotes the use of foam rolling as a warm-up activity prior to exercise (40). Foam rolling combined with active warm up routines are especially beneficial for sports where flexibility and force production are required (14, 20, 28, 30). However, foam rolling's acute effects on performance remain unclear. Pre-exercise foam rolling studies provide conflicting evidence for strength and power performance measures, but a lack of detrimental effects suggests that a single bout of foam rolling prior to exercise can acutely improve flexibility without hindering muscle performance (14, 20, 35, 36, 40). Most existing studies investigate the effects of pre-exercise foam rolling on flexibility, strength, and power measures, with a gap in the literature surrounding endurance performance measures (35).

Running economy, the oxygen uptake at a given running speed, can predict a large amount of variation in race performance (8). Better running economy can differentiate performance among runners with similar $\dot{V}O_{2max}$, as well as explain similar performances among runners with different $\dot{V}O_{2max}$ values (8, 9). Studies suggest that an optimal level of flexibility, that does not impede muscle stiffness, leads to improvements in running economy (33). Flexibility assists in optimizing stride length, especially at higher speeds of running, and running technique explains a large proportion of variance in running economy (10, 33). A recent study found that foam rolling prior to a bout of submaximal endurance running had no significant impact on physiological measures, perceived exertion, or running velocity, however findings were consistent with previous strength and power studies indicating that pre-exercise foam rolling did not impede performance (37). Despite the potential benefits of adding foam rolling as a warmup activity for endurance runners, few studies exist examining the effects of pre-exercise foam rolling on parameters of endurance performance. Therefore, the purpose of this study was to examine the acute effects of pre-exercise foam rolling on running economy at a self-selected 5-kilometer (km) pace. Running economy was expected to improve when foam rolling was used prior to the run.

METHODS

Participants

A power analysis (G*Power, Heinrich-Heine-Universität Düsseldorf) was run to determine the sample size necessary for this study. Beta and effect size were set to .80 and alpha level of .05. Sixteen runners volunteered for this study. Participants were recruited from local gyms, running clubs, and collegiate distance teams. Participant demographics are presented in Table 1. To be included in this study, participants had to compete in a race greater than or equal to 5 kilometers in the past 6 months. In addition, participants $\dot{V}O_{2peak}$ had to fall within the "Good, Excellent, or Superior" normative cardiovascular fitness criteria, organized by age and sex, by the ACSM Guidelines for Exercise Testing and Prescription (31). This criterion was evaluated during $\dot{V}O_{2peak}$ testing in the first session. If the volunteer did not meet this $\dot{V}O_{2peak}$ classification criteria, they did not meet the criteria for this study and were excluded.

Table 1. Participant demographics and training characteristics.

	Overall (n=16)
Age (years)	31.5±12.2
Height (cm)	172.2±8.2
Weight (kg)	67.5±7.0
Body Fat (%)	16.8±8.3
$\dot{V}O_{2peak}$ (mL/kg/min)	53.6±11.0
Days run per week	5.0±1.6
Miles run per week	33.0±23.7
Hours trained per week	11.1±6.3
Hours spent with other training methods per week	3.0±2.1

Prior to participation in this study, volunteers filled out an informed consent, medical history form, and physical activity questionnaire. The medical history form followed the American College of Sports Medicine (ACSM) guidelines for evaluation of medical supervision during exercise. Participants were excluded if they required medical supervision during exercise, had preexisting medical conditions, and/or current musculoskeletal injuries.

Participants were asked to self-report the number of days run per week, miles run per week, hours spent training per week, weekly hours engaged in other training methods, and personal best data of various races. Participants were instructed to refrain from vigorous exercise, caffeine, and alcohol 24 hours prior to testing sessions. Participants were asked to maintain the same nutritional habits prior to each testing and wear the same running shoes for each session. All research was carried out in accordance with the ethical standards of the International Journal of Exercise Science (25). This study was approved by the University's Institutional Review Board.

Protocol
Running economy is the energy demand needed during a submaximal bout of running, expressed as the submaximal $\dot{V}O_2$ at a given running speed (8, 33). In this study, running economy was expressed as oxygen consumption per kilometer (mL/kg/km) to allow for comparison between individuals running at similar relative intensities, but different absolute velocities, of running (9). Running economy has high variation between individuals, but within subjects it is a highly reliable measure, and has been used with various training interventions to detect changes in running performance (24).

Participants completed two sessions in the lab, one with a foam rolling intervention and one with a controlled rest period prior to the run, with a minimum of 48 hours of rest between the two sessions. The first session included collection of anthropometric measures, a baseline running economy test, and a maximal oxygen uptake ($\dot{V}O_{2peak}$) test. In the second session, participants completed the foam rolling intervention and running economy test. At the beginning of the first session, participants completed the required paperwork. Next, body composition was estimated using the COSMED Bod Pod (Chicago, IL, USA). Participants completed a standardized warm-up protocol, consisting of a 10-15-minute jog at the participants' self-preferred pace. Participants took a 12-minute rest period to control for the foam rolling intervention time. Participants then completed the running economy test, followed by the $\dot{V}O_{2peak}$ test.

Oxygen consumption and heart rate measures were monitored during the running economy and $\dot{V}O_{2peak}$ tests. A Polar heart rate monitor strap (Polar H10, Polar Electro Oy, Kempele, Finland) was placed around the participant's chest prior to warmup. A laboratory treadmill (Woodway Desmo, Woodway USA, Waukesha, WI, USA) was used for running tests. Oxygen consumption was measured using open circuit spirometry (ParvoMedics TrueOne 2400 Metabolic Measurement System, Salt Lake City, UT, USA). Expired gasses were collected breath by breath, and time-averaged every 15 seconds.

The $\dot{V}O_{2peak}$ treadmill protocol used continuous, 1-minute running stages following a modified McConnell protocol. The modified protocol has been found to be most efficient and perceived difficulty is decreased for the runner. Validity and reliability of the values are not affected by this adaptation (21, 22). Participants began at a 0% incline, with 0.5 km/h increase in speed until the speed reached self-selected race pace or maximum treadmill capacity (if race pace was above treadmill capacity). Once this speed was reached, the treadmill incline was increased 2% each minute. Testing was terminated at volitional fatigue. To ensure $\dot{V}O_{2peak}$ was reached during testing, the following criteria were checked: RPE $\geq$ 8, maximum heart rate within 10 bpm of age-predicted maximum, RER $\geq$ 1.1, and $\dot{V}O_2$ plateau. Participants who met the criteria for inclusion came back to complete the second testing session with foam rolling intervention, and received a foam rolling protocol tutorial.

The running economy protocol was a 4-minute run with a 1% incline at the participant's self-reported 5k race pace. The 1% incline was used to reflect the energetic cost of outdoor running (17). Running economy data was calculated from the last minute of the participant's run and calculated as the oxygen cost of running one kilometer (mL/kg/km). Running economy data can be collected up to speeds $\geq$ 90% $\dot{V}O_{2max}$ (9).

In session two, participants began by following the same warmup protocol as session one. Following warmup, participants completed the foam rolling intervention protocol. Foam rolling with a high-density roller (Power Systems LLC, Knoxville, TN) was applied bilaterally to the quadriceps, hamstrings, calves, and gluteal muscles for a duration of 90 seconds per muscle group. It is suggested that 90 seconds is a duration threshold to obtain acute benefits of foam rolling (14). Each muscle group was foam rolled unilaterally. Foam rolling was performed by the participant and supervised by a researcher. The researcher instructed the participant during foam rolling and timed the duration with a stopwatch. The participant used their bodyweight to apply pressure to soft tissues during the rolling motion. Pressure during rolling was self-determined by the participant and participants were instructed to roll to the point of pressure, but not pain. To apply foam rolling to the quadriceps, participants were in a prone position supported by their hands with the foam roller under their thighs. Participants applied foam rolling to their hamstrings, calves, and gluteal muscles seated on the foam roller while supported by their arms. On average, this process took 12 minutes.

Statistical Analysis

This study used a within-subjects design. A paired samples t-test was used to investigate the impact of foam rolling on running economy. Statistical analysis was performed using IBM SPSS (Version 26). Statistical significance was set at $p < .05$.

RESULTS

A post hoc power analysis was conducted to determine power for the study with use of sixteen subjects. Power was 0.64. Average running speed among participants was 14.8±4.2 km/h. A preliminary analysis was run to determine if differences existed between baseline running economy scores for the participants and no differences were found. A paired samples t-test was used to investigate the impact of the foam rolling intervention on running economy. Effect size was calculated as Cohen's *d,* using Cohen's classification of small (.20), medium (.60), and large (.80) effect size classifications for interpretation. Trained runners displayed improved running economy (a decrease in submaximal oxygen consumption) under the foam rolling condition (185.5±11.6 mL/kg/km) compared to the control condition (190.9±15.6 mL/kg/km), $t(15)=2.48$, $p=.026$, $d=.62$. Cohen's effect size suggests a moderate to large practical significance.

DISCUSSION

The purpose of this study was to determine if differences in running economy at 5 km race pace occurred when a pre-exercise foam rolling intervention was utilized compared to a controlled rest period. An improvement in running economy occurred when foam rolling was used prior to running at self-selected 5 km race pace. As limited research exists evaluating the acute effects of foam rolling on running economy, these findings provide evidence about the effects of foam rolling on a parameter of running performance. The results of our study are not able to determine the underlying mechanisms contributing to improvements in running economy observed with pre-run foam rolling; we are only able to document that these changes occurred, and that the observed effect has practical significance. Running economy is a net result of integrated physiological and biomechanical factors, and the specific components that contribute to running economy values are unique for each individual (19, 41). It is possible, and likely, that a modification of one or more factors that influence running economy could have occurred as a result of foam rolling, and that the relative contribution of factors differed per participant.

Foam rolling has been shown to acutely improve flexibility and range of motion measures (14, 20, 35, 40). Cross-sectional correlational studies investigating the relationship between flexibility and running economy are conflicting. Some studies show better flexibility is associated with reduced running economy, hypothesizing reductions in elastic energy return and stabilization due to the improved flexibility, while others fail to find a relationship (3, 39). However, active stiffness and passive flexibility are independent measures, and muscle flexibility is not a large contributor to the biomechanical stability of a joint (16). More consistent findings in chronic and acute experimental studies have shown that improvements in range of motion due to various stretching interventions do not alter running economy, suggesting that improvements in flexibility as a result of foam rolling may not hinder running performance (12, 26).

Optimal kinematic patterns are specific to the individual runner, but changes in an individual's running technique influence running economy (19, 38, 41). Oxygen uptake is lowest at a runner's self-selected stride length, and variations from this optimal stride length due to flexibility restrictions can reduce economy of running (6). Godges et al. (1989) found that soft-tissue mobilization with proprioceptive neuromuscular facilitation improved running economy for individuals with pre-treatment limitations in hip flexion and/or extension (11). In addition, interventions that improve hip flexibility have been shown to improve stride length (5). Therefore, an acute bout of foam rolling could act to mitigate stride length limitations due to restrictions in flexibility, thereby allowing a runner to achieve optimal stride length and better running economy. This could be particularly impactful at higher running velocities because as running speed increases, the importance of the hip extensors increases.

Another potential explanation for the improved running economy observed in the foam rolling session is an improvement in elastic and viscous properties of muscle and connective tissue. The increase in blood flow and tissue temperature resulting from mechanical pressure of foam rolling could contribute to the temperature-related benefits of warming up (23). As our control condition was passive rest, the foam rolling protocol could have contributed to improvements in performance much like an active warmup. In a traditional active warmup, muscle contractions produce heat, which increase the muscle temperature. Increases in muscle temperature quickly improve muscle blood flow and mechanical efficiency (29). Recent evidence shows that foam rolling improves sliding properties of fascial tissue, which is beneficial since muscle contractility improves with a decrease in viscous resistance and increased local vasodilation (20, 32). In addition, an acute bout of foam rolling improves arterial blood flow up to 30-minutes after rolling and increases the vasodilator nitric oxide's concentration, improving arterial function (15, 27).

The increases in local vasodilation from foam rolling may also have metabolic advantages that benefit substrate delivery and metabolite removal, as seen in traditional warmup protocols. Existing literature supports this theory, as a bout of foam rolling following high-intensity exercise was more effective at clearing lactate than passive rest (1). In contrast, Stroiney et al. (2020) did not find alterations in lactate clearance as a result of pre-exercise foam rolling, which may be a result of studying running velocities lower than lactate threshold (37). Finally, the increase in muscle temperature from a warmup improves oxygen release from hemoglobin and myoglobin, facilitating oxygen transport and delivery. Changes in oxygen transport and delivery may directly influence oxygen uptake measures (running economy). Therefore, both the contractile and metabolic properties of the muscle could have improved following foam rolling due to increases in blood flow contributing to a more efficient run.

The researchers acknowledge that this study has limitations. The order of the control and intervention experimental sessions was not randomized. Although all participants had prior treadmill running experience, this could have led to a potential learning effect. The foam rolling pressure was self-selected by participants, which could have led to uneven pressure applied by each individual. The results of this study should be interpreted with caution, as running economy measures are highly specific to the population and environment. Our study investigated running economy at self-selected 5 km race pace, while most studies investigating flexibility were performed at a lower submaximal %$\dot{V}O_2$. Therefore, improvements in running economy documented in our study could be a result of stride length optimization having a bigger impact on faster speeds. Finally, we did not consider the psychological effects of foam rolling on an individual. Psychological effects of self-myofascial release may contribute to athlete performance as a non-temperature benefit of using a warmup protocol by reducing perceptions of fatigue and soreness that would not be observed in physiological or biomechanical measures (13).

As foam rolling was the only experimental group in this study, future studies could seek to investigate the effects of various warm-up protocols compared to, or including, foam rolling as a pre-exercise routine. As foam rolling exerts influences similar to those observed in various warm up protocols, the efficacy of foam rolling compared to other warm-up methods would provide athletes and coaches more information on how to effectively use foam rolling prior to a run. In addition, a comparison of foam rolling efficacy to other forms of myofascial release prior to running tasks is needed. Previous literature suggests that running economy improves when flexibility restrictions are corrected, and future studies should examine whether foam rolling could improve running performance in those with pre-exercise flexibility limitations in the lower body. Finally, the examination of both physiological and psychological measures of an acute bout of foam rolling before a bout of running is needed.

In conclusion, foam rolling may be beneficial in improving running economy while running at a self-selected race pace. No decreases in performance were found, which is beneficial to runners who utilize self-myofascial release tools as a part of their race preparations. Future research is needed to determine what physiological and biomechanical mechanisms are affected by the use of self-myofascial release. This study provides further support for past research which suggests foam rolling is an effective warm-up strategy prior to exercise.

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PURPOSE

The purpose of this study was to determine whether using foam rolling as a warm up strategy prior to a high intensity run impacted economy of running in trained distance runners.

KEY FINDINGS

- Running economy improved when runners used foam rolling prior to a run
- Pre-run foam rolling may be beneficial for improving running economy in trained runners
- Foam rolling does not appear to reduce running performance measures
- Foam rolling is an acceptable warm-up strategy for distance runners who wish to include this method in their pre-run routine

RATIONALE

Running economy is a predictor of running performance. In two runners with the same $\dot{V}O_{2max}$, the runner with lower running economy will be able to run at faster speeds, and therefore have better performance. Changes in a runner's technique impact running economy. For example, restrictions in hip mobility can reduce a runner's stride length, and this limitation may result in a reduced economy of running. Warm-up strategies that address flexibility prior to a run may have a positive impact on running economy in distance runners. Foam rolling is a popular warm-up strategy for distance runners. A single application of foam rolling increases blood flow to muscle and muscular temperature, and improves range of motion for up to 30 minutes. It is important to consider the impact of warm-up protocols on measures of the runner's performance.

THE STUDY

Participants in this study were trained runners who reported running on average 5.0±1.6 days per week, 33±23.7 miles per week, 11.1±6.3 hours trained per week, and 3.0±2.1 hours training with other methods per week. Runners were 31.5±12.2 years, 172.2±8.2 cm, 67.5±7.0 kg, 16.8±8.3 % body fat, 53.6±11.0 $\dot{V}O_{2peak}$.

Runners completed one session of running without foam rolling and one session with foam rolling prior to a treadmill run. Runners completed a 10-to-15-minute warmup jog, followed by either a rest period or the foam rolling protocol, and then completed a 4-minute run on the treadmill. Intensity of running was the runners self-selected 5k race pace, based on recent race results. Average speed of the runners was approximately a 6:30 mile pace (14.8±4.2 km/h). Running economy data was collected during both runs, and compared for statistical analysis. Foam rolling was applied to one leg at a time, on both legs, at the hamstrings, quadriceps, gluteal, and calf muscles for 90 second per muscle group. Pressure during rolling was self-determined by the participants, who were instructed to roll to the point of pressure but not pain.