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Technical Note

Foam Rolling on the Whole Leg and Its Immediate Effects on Postural Control in Collegiate Female Athletes

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ABSTRACT

International Journal of Exercise Science 17(1): 954-964, 2024. The maintenance of body posture relies on mechanoreceptors, suggesting myofascial release could assist postural control. The effects of this have not been well documented, providing room for this investigation. Twenty-one female athletes spent approximately 2.5 minutes foam rolling the calf and thigh muscles on one leg then repeated on opposite leg for a total of 5 minutes. Center of Pressure (CoP) and Limit of Stability (LoS) were assessed using a Bertec posturography plate before (pre-) and after (post-) foam rolling. CoP was measured with eyes open stable surface (EOSS), or eyes closed stable surface (ECSS) and perturbed surface both eyes open (EOPS) and eye closed (ECPS). conditions. LoS was evaluated in the Anterior, Posterior, Left, and Right Directions. A significant effect of Condition for CoP showed ECPS Condition was greatest at both pre- and post-foam rolling ($p<0.001$). A significant main effect of Direction ($p<0.001$) showed LoS was greatest in the frontal plane Directions compared to sagittal plane ($p<0.01$). A significant effect of Time ($p<0.05$) indicated LoS decreased from Pre- to Post-foam rolling (mean change = 0.569 cm). The study demonstrated that acute effects of self-myofascial release via foam-rolling of the lower extremities can influence postural control.

KEY WORDS: Balance, limit of stability, center of pressure, self-myofascial release, proprioception

INTRODUCTION

Myofascial release is a popular therapy technique used among fitness and health care professionals to alleviate perceived pain from physical trauma, improve blood flow throughout the body, increase mobility, and generally improve functioning of osseous structures, nerves, and organs (5, 29). The changes that occur from this manipulation have been attributed to the controlled and forceful application of myofascial release that stretches and elongates muscular and fascial structures of the body (14, 29). Understanding the influence of manipulated pressure and release to the fascia surrounding muscle tissue is critical for physicians and therapists to elicit the desired effects of this treatment approach.

Foam rolling has been implemented by physical therapists to produce the desired effects of myofascial release when a clinician is not present to administer the treatment. Those who consider themselves to be 'athletes' are generally in need of a tool such as this to gain the benefits of myofascial release in a cost-effective and self-guided alternative to clinical care. Foam rollers have typically been used to increase and promote post-exercise recovery of athletes (1, 20). Post-exercise recovery is greatly dependent on perceived feelings of delayed-onset muscle soreness (DOMS) and previous investigations have observed a positive effect of foam rolling on tissue repair, DOMS, and subsequent exercise performance (1, 17, 20). While athletic performance is important, performance cannot occur if an injury is present. Studies have suggested that foam rolling may decrease injury incidence via improved range of motion (ROM) and joint flexibility (9, 18). The evidence from past research greatly supports the positive effects of foam rolling on athletic performance and injury-related measures such as recovery and flexibility, yet it is still unknown how foam rolling may affect stability measures such as postural control.

Postural control is the body's ability to maintain an upright position within a defined space and is regulated by two mechanisms: tonic muscle activity and compensation in response to internal and external stimuli (16). For the body to maintain upright positioning, it must collect and use accurate somatosensory, visual, and vestibular inputs that work concurrently (17). Within the somatosensory system are mechanoreceptors that provide information on the body's position in space, termed proprioception (2). Mechanoreceptors are in muscular and connective tissue such as muscle spindles and Golgi tendon organs (2), and work by sensing and measuring the joints' relative position to one another as it moves through a range of motion (15). Interest has grown in observing the immediate effects of myofascial release on the body's proprioceptive quality through stretching (7). Additional interventions such as strength or dynamic, quick movements may influence proprioceptive sensing thresholds by improving mechanoreceptor messaging, following a bout of foam rolling (19, 22). However, research linking changes to proprioception following foam rolling and postural control has been limited to field test studies on male soccer athletes or jumper sport enthusiasts reporting dynamic Y-balance scores and perceived balance confidence (10, 12, 24, 25), with no studies measuring postural control using laboratory force plate data, especially static balance scores.

There has been a major gap in the literature when comparing physiological changes between men and women, especially within the central nervous system (4). Factors such as blood flow or motor neuron transmission could differentiate changes between the gender (4, 30). Females have a greater periodic variation in synaptic input to motor units that could have a greater effect on the nervous system response compared to men (4).

Therefore, the purpose of this investigation was to further investigate the effects of foam rolling on female athletes' proprioceptive sensitivity and resulting muscle regulation, as measured by two aspects of postural control: center of pressure (CoP) and limits of stability (LoS). There are no current valid methods of measuring CoP or LoS though field testing and the use of force plate data has been investigated in the past especially only on women using perturbed surfaces to obtain specific changes to these parameters in various populations (26). We hypothesized that following foam rolling of the entire lower limb, a change in proprioceptive sensitivity occurs and influences the regulation of muscle activation, which would be shown as a change in either CoP and/or LoS testing.

METHODS

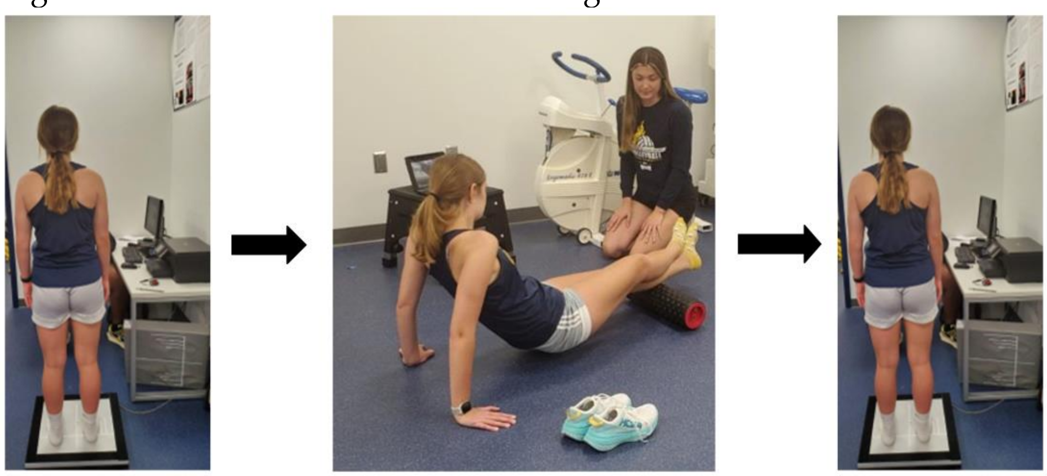
Participants

21 female collegiate athletes (Age 20.10 $\pm$ 0.77 years; Weight 69.10 $\pm$ 1.26 kg; Height 171.64 $\pm$ 1.32 cm) were recruited from a midwestern college campus via convenience sampling from a variety of sports offered at the college. Inclusion criteria required all participants to be over the age of 19 (or to have obtained parental consent due to state law) and be a currently eligible student-athlete as defined by the National Association of Intercollegiate Athletics. Exclusion criteria required all participants to have no reported injuries to the lower extremities or conditions that would affect their balance within the last three months, including current visual or vestibular diagnoses. This study was completed in accordance with the Declaration of Helsinki and received approval from a midwestern university Institutional Review Board (IRB # CSM 2124). This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (21). All participants provided written informed consents prior to enrolling in the investigation. An ANOVA priori power analysis was performed previously to the study with a predicted n size of 20 and power was determined at 0.99 ($p < 0.05$). Effect sizes interpretation was set as small for ≤ 0.2, medium for 0.5, and large for ≥ 0.8 (8). Based on using 8 variable groups, the effect size was calculated at 0.622.

Protocol

Balance testing was completed using a Bertec® Computerized Posturography Force Plate (Bertec Corporation, Columbus, OH). This valid and reliable laboratory instrument quantifies a subject's ability to maintain balance while in the upright position through sensors that measure ground reactive forces between the subject's feet and the force plate within 10 seconds. Participants were instructed to stand barefoot on the force plate with their medial malleolus of their ankles parallel to the horizontal line of the force plate as well as to have their lateral calcaneus of each foot aligned to the appropriate midline (26). Each participant's 4 static postural sway assessments were recorded via CoP measurements under four conditions: eyes open standing on a stable surface (EOSS), eyes closed standing on a stable surface (ECSS), eyes open standing on a perturbed/unstable surface (EOPS), and eyes closed standing on a perturbed/unstable surface (ECPS). The perturbed surface used was a BalanceCheckTM Foam pad (0.5 x 0.5 x 0.075 m) provided by the manufacturer made of dense foam materials with similar markings as the force plate to help position the subject's feet on top of the force plate provided by Bertec®. Once CoP tests were completed, each participant's LoS was measured by having them lean both anteriorly (LoSA) and posteriorly (LoSP) in the sagittal plane, followed by leaning to the left (LoSL) and right (LoSR) in the frontal plane. The 4 CoP tests were conducted for 10 seconds each of static posture, while LoS completion was time dependent on each participant. The postural sway was determined by CoP, representing static postural stability, while the LoS scores accounted for dynamic postural stability (23). Each participant arrived within a 10-minute stagger among all subjects, allowing an even time distribution for administering all 8 balance tests before the 2.5-minute intervention. Pre-balance testing was completed first upon arrival to gather baseline data of all 8 balance measurements and then again following the foam rolling protocol to assess any changes due to self-myofascial release in the same staggered timelines to standardize time frequencies between balance testing and intervention (Scheme 1). Since participants served as their own controls and randomization would not affect results, participants were tested based on their schedule and availability.

The self-myofascial release foam rolling protocol was completed using a Rocktape® Rock N Roll (66 x 26 cm) foam roller (Rocktape, Durham, NC) made of carbon foam, textured with 600 equally spaced nodules (3 cm apart) protruding 1.5 cm (about 0.59 in) high, and weighing 1.7 kgs. Participants were instructed to roll each whole leg for approximately two and a half minutes. Participants first rolled the calf muscles for two 30-second intervals followed by the hamstrings for two 30-second intervals and then quadriceps for a single 30-second interval by following cued instructions of a timed video. Then, subjects repeated the same exact process on the opposite leg for approximately five total minutes of foam rolling. The foam rolling was to be completed at a five second cadence whereby the participant rolled from the proximal end to the distal end of the muscle group over the course of five seconds before repeating the process from distal to proximal resulting in six passes over each muscle group per interval. Participants watched a video recording of the technique while they foam rolled to ensure they would maintain cadence. Participants were also presented with a 1 to 10 visual analog scale detailing intensity levels whereby 1 represented no discomfort and 10 represented excruciating pain (13). All participants were instructed to maintain an intensity of 7 out of 10, corresponding to a moderate degree of discomfort from the foam rolling intervention.



Scheme 1. Protocol Procedures.

Statistical Analysis

Separate 4 X 2 (Condition X Time & Direction X Time) repeated-measures analysis of variance (ANOVA) were used to examine the acute changes in CoP condition (EOSS, ECSS, EOPS, ECSS) and LoS Direction (LoSA, LoSP, LoSL, LoSR) over Time (Pre- and Post-foam rolling). Analyses were carried out using SPSS v. 28 (IBM, Armonk, NY). When sphericity was violated, the

Greenhouse-Geisser corrected p-value was used. Post hoc Bonferroni-corrected t-tests were used to examine any significant differences. All analysis were run with ∝=0.05. Partial eta squared (η2) was used to estimate the effect sizes of any differences (η2 of 0.01 – 0.059 = small effect; η2 of 0.06 – 0.139 = medium effect; η2 ≥ 0.140 = large effect).

RESULTS

Center of Pressure: Average outcomes for all CoP conditions are displayed in Table 1. Statistical outcomes are summarized in Table 2. There was no significant main effect for Time (p>0.8; η2=0.001) which indicates that CoP scores did not change from Pre- to Post-foam rolling. There was however a significant main effect for Condition (p<0.001; η2=0.716). Follow-up Bonferroni-corrected t-tests showed that the CoP for the ECPS condition was greater than the EOSS, ECSS, and EOPS Conditions at pre-foam rolling (mean differences = 0.267, 0.195, & 0.199, respectively; p<0.001). While the CoP for ECPS was still significantly greater than the EOSS and ECSS Conditions at post-foam rolling (mean differences = 0.170 & 0.127, respectively; p<0.001), it was not significantly greater than the EOPS Condition (mean difference = 0.086; p>0.3). The EOSS, ECSS, and EOPS Conditions were not significantly different from one another at either pre- (mean difference range = 0.004 – 0.072; p>0.1) post-foam rolling (mean difference range = 0.040 – 0.084; p>0.2). No significant interaction effect was detected (p = 0.095; η2= 0.279).

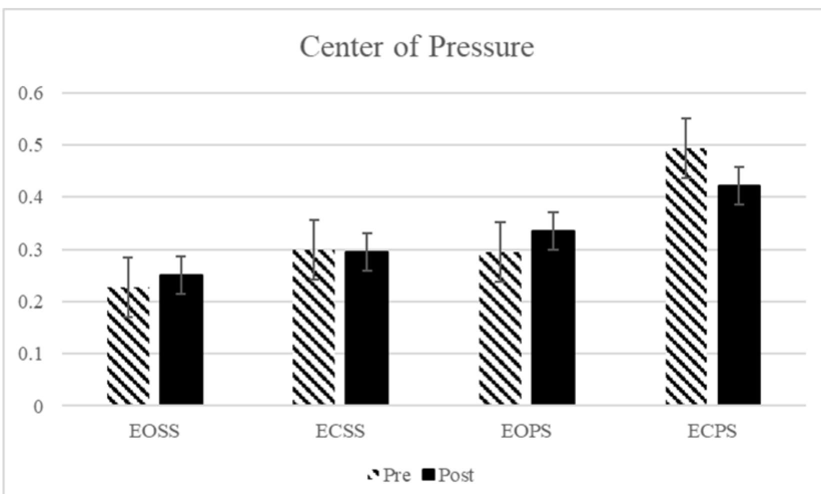


Figure 1. Center of Pressure, Pre- to Post-Foam Rolling changes measured in cm.

Table 1. Static Postural Stability (Center of Pressure, CoP)

CoP Condition	Pre-foam rolling (cm)		Post-foam rolling (cm)		Cohen's d effect size
	Avg	SD	Avg	SD	
EOSS	0.227	0.027	0.251	0.019	1.03
ECSS	0.299	0.026	0.295	0.033	0.13
EOPS	0.295	0.021	0.335	0.033	1.45
ECPS	0.494	0.039	0.421	0.033	2.02

(cm) = centimeters EOSS = eyes open, stable surface; ECSS = eyes closed, stable surface; EOPS = eyes open, perturbed surface; ECPS = eyes closed, perturbed surface; data presented as mean ± SEM.

Table 2. Statistical Outcomes – Center of Pressure.

Effect	Significance (p)	Effect Size (η^2)	Observed Power
Time	0.874	0.001	0.053
Condition	<0.001	0.716	1.000
Time X Condition	0.095	0.279	0.518

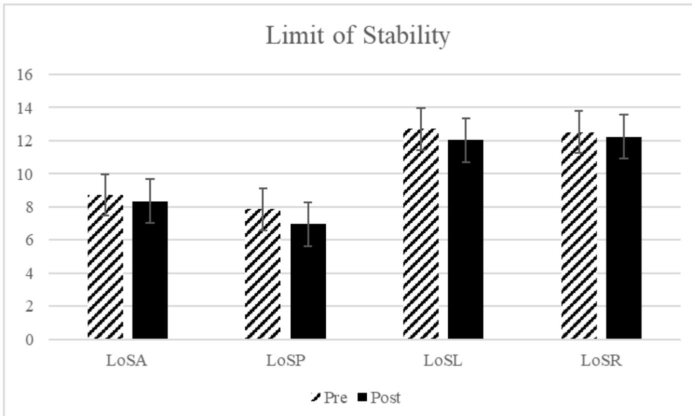


Figure 2. Limit of Stability, Pre- to Post-Foam Rolling.

Table 3. Dynamic Postural Sway (Limit of Stability, LoS changes from Pre to Post).

LoS Condition	Pre-foam rolling (cm)		Post-foam rolling (cm)		Cohen's d effect size
	Avg	SD	Avg	SD	
LoSA	8.721	0.532	8.331	0.485	0.77
LoSP	7.869	0.469	6.961	0.420	2.04
LoSL	12.718	0.584	12.034	0.573	1.18
LoSR	12.528	0.520	12.235	0.614	0.51

(cm) = centimeters; Anterior = LoSA; Posterior = LoSP; Left = LoSL; Right = LoSR

Table 4. Statistical Outcomes – Limit of Stability.

Effect	Significance (p)	Effect Size (η^2)	Observed Power
Time	0.028	0.210	0.616
Direction	<0.001	0.641	1.000
Time X Direction	0.7	0.019	0.518

Limit of Stability: Average outcomes for LoS in all directions are displayed in Table 3 and Figure 2. Statistical outcomes are summarized in Table 4. There was a significant main effect for Time ($p<0.05$; $\eta 2 = 0.210$) which indicated that, on average, LoS tended to decrease from pre- to post-foam rolling (mean difference = 0.569). There was also a significant main effect for Direction ($p<0.001$; $\eta 2 = 0.641$), which indicated that LoS differed between Directions. Follow-up Bonferroni-corrected t-tests showed that LoS in the Left Direction was significantly greater than both the Anterior and Posterior Directions at both pre- (mean differences = 3.997 & 4.843, respectively; $p<0.01$) and post-foam rolling (mean differences = 3.703 & 5.073, respectively; $p<0.001$). Similarly, LoS in the Right Direction was also greater than both the Anterior and Posterior Directions at both pre- (mean difference = 3.807 & 4.659; $p<0.001$) and post-foam rolling (mean difference = 3.904 & 5.274; $p<0.001$). However, LoS did not differ between the Left and Right Directions at either pre- or post-foam rolling (mean difference = 0.190 & 0.201, respectively; $p>0.1$) nor did they differ between the Anterior and Posterior Directions at either pre- or post-foam rolling (mean difference = 0.852 & 0.719, respectively; $p>0.4$). No significant interaction was detected ($p>0.7$; $\eta 2 = 0.019$).

DISCUSSION

The purpose of this investigation was to study the acute effects of self-myofascial release via whole leg foam rolling on postural control in college aged female athletes. This novel investigation, observing strictly the whole leg on CoP and LoS using a force plate has not been performed to our knowledge, especially on women only. Previous research focused on using dynamic field balance testing on mainly men or jumping sport athletes, and not strictly women athletes (11, 23). Also, past studies observed foam rolling interventions over several days and weeks, using a longer intervention time at a similar intensity threshold. We hypothesized that following foam rolling of the entire lower limb, a change in proprioceptive sensitivity occurs and influences the regulation of muscle activation, which would be shown as a change in either CoP and/or LoS testing. We did not observe a significant interaction between foam rolling the whole leg and static CoP testing except for ECPS ($p < .001$). It is likely that the immediate effects of foam rolling do not interfere with the mechanisms that maintain static CoP in healthy young athletes except under instability and without visual references. Mechanoreceptors, Golgi tendon organs, and muscle joint spindles responsible for proprioception have been theorized to respond most with movement, which further explains the lack of change in static CoP scores with EOSS, ECSS, & EOPS (3). However, with ECPS, since the ankle joint is being manipulated under perturbed conditions, the ankle proprioceptive elements of central processing from the central nervous system, along with other mechanoreceptors could have enabled further integration for increased balance control (16, 17, 27).

In dynamic postural control conditions, we did observe a significant decrease in LoS scores post intervention for all conditions. Therefore, our results support our hypothesis by showing an overall decrease in dynamic LoS in female athletes. Past research has supported the neurological and morphological argument for these changes in mainly men. From the morphological standpoint, when pressure is manipulated and applied to the specified muscle, restoration in the fascia occurs, taking pressure off blood vessels and nerves and improving joint range of motion, thereby establishing its effect on muscle tissue (4, 5, 18). Because this relationship exists, it could explain why LoS scores decreased overall from foam rolling the whole leg. However, morphologically induced changes have been recently debated in the literature (27). Additionally, the decrease in LoS may be due to the neurological aspect in female athletes. A decrease in spinal excitability has been shown to occur following massage application (6). Mechanoreceptors that exist within muscle and connective tissue are inhibited by deep pressure, causing a decrease in the pressure-pain threshold and decrease in muscle excitability (28). Therefore, the decreased LoS findings of this study may be attributed to the potentially lowered ability to sense position in space and control movements dynamically that prompted subjects to protectively move less far. Ultimately, it is possible that a combination of these two aspects led to the changes we observed since it is hard to differentiate both phenomenon's natural occurrence in the body. Our findings further support both arguments and show that application of self-myofascial release (SMR) can have an overall effect in dynamic postural sway of the body.

Additionally, there was a significantly greater change in right and left directions compared to anterior and posterior directions following foam rolling. Stated more simply, participants moved greater distances left and right compared to forward and backwards post intervention. These findings are likely due to the intervention mainly targeting muscles in the anterior and posterior aspects of the lower extremities, which in turn resulted in acute morphological and neurological changes in women as previously mentioned (4, 5, 6, 11, 18, 29). Due to the changes in the targeted muscles, the body protectively limited movement outside the base of support to avoid falls (11). Since the intervention did not target lateral or medial muscles, it can be inferred that participants-maintained a near baseline level of proprioception to allow for frontal plane movement.

In studying changes in CoP and LoS in women only, much of the research that exists has primarily been carried out using dynamic Y-balance or Star Excursion tests for instrumentation (10, 25). This study aimed to broaden this area of research with different experimentation methods as well as testing protocol using a computerized posturography plate, introducing a different mechanism of instrumentation to study both static and dynamic aspects of balance in female athletes.

This study is not without limitations. The sample population was only female. It is not advised to form inferences and generalizations to the male population based on the findings of this study. It is not certain that all participants followed the guidelines of foam rolling as they were informed to do so. The current design did not include a control group or another experimental group to compare balance testing results. No differentiation between sports were conducted. Future studies should aim to study this interaction effect within different populations to gain a better understanding of who can benefit from roller massage therapy in this aspect of balance. Additionally, future studies should include different sport athletes, special populations, the use of electromyography (EMG), and observing if increasing duration of the intervention could determine the effects on postural control, as this may help determine practical guidelines to follow for optimal benefit.

Conclusion: The findings of the study may be helpful in several aspects of sports performance. In general, we observed foam rolling the entire leg had the most significant changes in LoS, resulting in a decreased ability to move their center of mass outside their base of support. Therefore, sporting events which demand large physical dynamic movements of the body may choose to limit the use of foam rolling prior to performance to avoid this decrease in LoS.

Additionally, sporting events that require athletes to move dynamically may be at greater risk of injury if foam rolling the entire leg is performed as a warmup.

Practical Applications: The findings of the study may be helpful in several aspects of sports performance. From our CoP results, ankle proprioception could be enhanced under unstable playing conditions based on results of ECPS ($p < .001$). From our LoS results, foam rolling of the whole leg resulted in significant reductions in the frontal and sagittal planes ($p < .01$). Sporting events which require balance control towards lateral reaching movements may benefit from short interval foam rolling of the calves vs. whole leg interventions, based on the results from this investigation.

Limitations of the Study: This study is not absent of limitations that should be addressed. The use of the Visual Analog Scale is only an exemplar for perceived level of intensity during the foam rolling session. The experience of perceived pain and intensity level may have differed across the subject population. Guidelines for the specific foam rolling technique were provided through instructional demonstration as well as verbal queuing provided by the investigators of the study; however, it is not guaranteed that all participants followed the required protocol. Also, the use of neurological measures such as EMG readings could provide additional answers on changes in postural sway. Lastly, the participants were only college aged women athletes.

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