The Acute Effects of Foam Rolling and Dynamic Stretching on Athletic Performance: A Critically Appraised Topic

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Clinical Scenario: Dynamic stretching and foam rolling are commonly used by athletes to reduce injury and enhance recovery, thereby improving athletic performance. In contrast to dynamic stretching, little research has been conducted on the acute effects of foam rolling as part of the preexercise warm-up routine. Previously, when researchers implemented foam rolling with static stretching as a warm-up, some found that foam rolling slightly improved flexibility and performance outcomes. More recent research has shown that dynamic stretching is favorable to static stretching when used as a warm-up strategy. Therefore, adding foam rolling to dynamic stretching is hypothesized to create more significant improvements in flexibility and performance compared with adding foam rolling to static stretching. **Focused Clinical Question:** In active individuals, does foam rolling in addition to dynamic stretching lead to enhanced performance compared with dynamic stretching alone? **Summary of Key Findings:** Four randomized controlled trials were included. Two studies concluded that the addition of foam rolling to dynamic stretching increased vertical jump height more than dynamic stretching alone, while 2 studies found no difference between these treatment groups. Two studies concluded that the addition of foam rolling increased agility performance compared with dynamic stretching alone, while one study found no difference between treatment groups and one study did not measure agility. All 4 studies reviewed concluded that foam rolling did not improve flexibility more than dynamic stretching alone. **Clinical Bottom Line:** Foam rolling in conjunction with dynamic stretching may further improve an athlete's agility and power output; however, little improvement has been observed with foam rolling in regard to athlete flexibility when compared with completing dynamic stretching programs alone. **Strength of Recommendation:** Inconsistent findings from 4 randomized controlled trials suggest there is Grade C evidence to support the inclusion of foam rolling in a dynamic warm-up.

Keywords: manual therapy, agility, flexibility, power

Clinical Scenario

Dynamic stretching and foam rolling are common practices employed by sports medicine and strength and conditioning professionals to enhance athletic performance.^{1,2} More commonly, dynamic stretching is used as a warm-up prior to physical activity, while foam rolling is typically used as a recovery strategy to reduce delayed onset muscle soreness and subsequently improve performance. Previous research supports that both of these methods can improve athletic performance through physiological changes occurring to the muscle.²⁻⁵ Specifically, dynamic stretching causes increased blood flow to the muscle, increased muscle tissue temperature, and increased nerve conduction velocity.⁶ Furthermore, dynamic stretching can lead to decreased muscle stiffness and positive changes in energy system metabolism.⁶ Similarly, foam rolling, as a type of self-myofascial release, may improve performance through increasing arterial dilation,^{1,2} reducing fascial restrictions,^{6,7} and enhancing muscle elasticity and neurological feedback.²

In efforts to simultaneously improve flexibility and athletic performance, researchers have studied foam rolling combined with static stretching, with results yielding only small improvements in performance.¹ Unfortunately, although static stretching may increase flexibility, when implemented alone as a warm-up technique prior to exercise, it has detrimental effects on athletic

performance^{1,8} and may lead to increased risk of injury.⁸ In contrast, when used prior to exercise, dynamic stretching has been shown to improve speed, balance, and power,¹ while still increasing flexibility.⁸ Preliminary evidence suggests that dynamic stretching may be a more favorable option compared with static stretching.

Recently, researchers have begun studying the effect of foam rolling as a warm-up technique on flexibility and athletic performance as it has become a popular activity among strength and conditioning coaches.^{1,2,6,7} Research evaluating the effects of a combined warm-up, for example, dynamic stretching and foam rolling, are important in determining the most beneficial method of preparing for athletic performance.¹

Focused Clinical Question

In active individuals, does the combination of foam rolling and dynamic stretching lead to enhanced performance compared with dynamic stretching alone?

Summary of Search, "Best Evidence" Appraised, and Key Findings

- PubMed and EBSCOhost databases were searched to identify articles of level 2 evidence or higher. These studies examined the combined effects of dynamic stretching and foam rolling, compared with a control group, on athletic performance. All studies measured vertical jump height (in centimeters) and range of motion, measured by either sit-and-reach or goniometry.

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- A total of 7 studies were identified. Three studies were eliminated because they did not measure the desired outcomes for this critically appraised topic. The search identified 4 studies that met all criteria. All 4 studies were randomized controlled trials; 3 of the studies used repeated-measures designs.
- Richman et al² compared the effects of light walking plus dynamic stretching and dynamic stretching plus foam rolling on flexibility and performance in healthy, female athletes. The researchers noted statistically significant improvements in vertical jump height (in centimeters) in the dynamic stretching plus foam rolling groups compared with the light walking plus dynamic stretching group.² No significant improvements were noted for flexibility or agility between treatment groups.²
- Peacock et al¹ compared the effects of dynamic stretching alone to dynamic stretching plus foam rolling on flexibility and performance in healthy, male athletes. The researchers noted statistically significant improvements in vertical jump height (in centimeters) and completion times for the pro-agility shuttle test (also known as the 5-10-5 shuttle drill) in the dynamic stretching plus foam rolling group compared with the dynamic stretching alone group.¹ No significant differences between treatment groups were noted for flexibility.¹
- Smith et al⁶ compared the effects of rest, foam rolling alone, dynamic stretching alone, and foam rolling plus dynamic stretching on flexibility and athletic performance in healthy, male and female participants. This study found significant improvements in vertical jump height (in centimeters) in the dynamic stretching plus foam rolling group.⁶ Increased flexibility was also noted in the foam rolling group immediately postintervention, but this was not significantly different from the other treatment groups.⁶ Unlike the Richman et al² and Peacock et al¹ studies, Smith et al⁶ did not assess agility as part of the testing battery.
- D'Amico and Gillis⁹ compared the effects of foam rolling plus a dynamic warm-up compared with a dynamic warm-up alone on flexibility and athletic performance in healthy, male and female participants with exercise-induced muscle damage. The researchers found no significant between-group differences for vertical jump or flexibility. After inducing muscle soreness, the researchers noted that the foam rolling group completed an agility test (*t* test) significantly faster compared with the dynamic warm-up group.
- Results of 2 of the 4 studies supported the use of foam rolling plus dynamic stretching to improve athletic performance, while Smith et al⁶ suggested the use of foam rolling at different times, rather than as a warm-up. D'Amico and Gillis⁹ suggested that foam rolling may be a beneficial addition to the warm-up, specifically to improve agility when recovering from muscle soreness.

Clinical Bottom Line

There is moderate evidence to suggest that the inclusion of foam rolling to a dynamic warm-up protocol has an increased effect on power and agility over the completion of dynamic stretching alone. The inclusion of foam rolling seems to have little effect on flexibility when compared with dynamic stretching alone; indicating that dynamic stretching and foam rolling may affect different aspects of athletic performance.

Strength of Recommendation

Based on the inconsistent findings among the 4 Centre for Evidence-Based Medicine level 2 studies included in this critically appraised topic, there is Grade C evidence to support the use of foam rolling with dynamic stretching as a warm-up to improve performance.

Search Strategy

Terms Used to Guide Search Strategy

- **P**opulation: active individuals
- **I**ntervention: dynamic stretching + foam rolling
- **C**omparison: dynamic stretching alone
- **O**utcome: athletic performance, flexibility

Sources of Evidence Searched

- PubMed
- Medline
- SPORTDiscus
- CINAHL
- Literature references hand-searched for additional resources

Inclusion and Exclusion Criteria

Inclusion

- Interventions of dynamic stretching and foam rolling
- Assessment of hamstring function via sit-and-reach and/or goniometric measurements
- Centre for Evidence-Based Medicine level 2 evidence or higher
- Articles in English
- Articles published during or after 2014

Exclusion

- Outcome measures that did not include sit-and-reach, goniometry, and vertical jump
- Articles that did not provide means or SDs for at least one outcome measure
- Studies scoring <5/10 on the PEDro scale

Results of Search

Four studies were identified as meeting all inclusion/exclusion criteria and are categorized based on the 2011 Centre of Evidence-Based Medicine Levels of Evidence in Table 1.^{1,2,6,9}

Table 1 Summary of Study Designs

Level of evidence	Study design	Number located	Reference
2	Randomized control trial, within subject	4	Richman et al ² Smith et al ⁶ Peacock et al ¹ D'Amico and Gillis ⁹

Best Evidence

The included studies provide the best evidence to answer the clinical question as they met all inclusion and exclusion criteria. All 4 studies were small sample randomized controlled trials that provided level 2 evidence and examined the effects associated with combined treatments of dynamic stretching and foam rolling on athletic performance. Table 2 describes these studies.

Implications for Practice, Education, and Future Research

Research has shown that both dynamic stretching and foam rolling can benefit athletic performance³⁻⁵ and are frequently used in the sports medicine and strength and conditioning fields.⁸ Until recently, little research had been conducted to determine the effects of a combined treatment of dynamic stretching and foam rolling. Based on the results of the included studies, it seems as though a combined warm-up may have differing effects on athletic performance compared with completing a dynamic warm-up alone. Specifically, these preliminary results suggest that dynamic stretching and foam rolling may improve different aspects of athletic performance, with dynamic stretching benefiting flexibility and foam rolling benefiting agility and power.

In the Richman et al² study, both treatment groups demonstrated similar acute improvements in flexibility, but the researchers found that participants completing a combined treatment (self-myofascial release with foam rolling and dynamic stretching) performed significantly better in the vertical jump test compared with those in the dynamic stretching alone group. These results are supported by Peacock et al¹ who also found significantly better acute performance results in their combined warm-up group versus the dynamic stretching alone group. Specifically, Peacock et al¹ found acute improvements in agility as well as power performance, although no differences were found in flexibility in the combined warm-up group compared with the dynamic stretching alone group. Similarly, Smith et al⁶ found no differences in flexibility between treatment groups but found improvements in vertical jump height in a combined warm-up group compared with the foam rolling alone or complete rest groups. These results, however, did not significantly differ from the dynamic stretching alone group.⁶ Finally, in contrast, D'Amico and Gillis⁹ only found improvements in participant agility, while power and flexibility remained equivocal between the combined and dynamic warm-up alone groups. In conclusion, although the results from the studies are somewhat inconsistent, the addition of foam rolling to a dynamic stretching warm-up seems to have the largest effect on an individual's power output and agility performance with little effect on flexibility.

While all studies assessed the same outcome measures of flexibility and lower extremity power, some used different methods of measurement. For example, 3 of 4 studies used a standard sit-and-reach box to determine participant flexibility, while D'Amico and Gillis⁹ used goniometric measurements. Sit-and-reach assessments evaluate hamstring and low back flexibility, while goniometric measurement of hip flexion isolates the hamstring.¹⁰ Therefore, the differences in results between studies may be explained by the different measurement methods.

Although all studies used vertical jump height to determine lower extremity power, 3 of 4 studies measured vertical jump directly using a Vertec device (type 9260AA6; Kistler, Amherst, NY), while Smith et al⁶ indirectly measured jump height with a

force plate. While both of these measures have excellent reliability,¹¹ the differences in measurement techniques allow for differing results and interpretations. Previous research has found that the Vertec device measures significantly lower vertical jump heights when compared with a criterion laboratory force plate^{12,13}; however, the measurements are highly correlated.¹³ These results suggest that although the Vertec may provide a reasonable estimate of lower extremity power, it may not be an accurate measure of true vertical jump height.¹² Finally, only 3 of the 4 studies assessed agility changes in the participants. Because only 3 of the studies measured agility, the results may not hold as much significance as flexibility and vertical jump which were measured in all the included studies.

Both Richman et al² and Smith et al⁶ included participants who had no previous experience using foam rolling as a form of self-myofascial release. A participant's lack of experience could have affected the efficacy of the treatment and possibly created differing results compared with a person experienced in foam rolling. In addition to having minimal or no previous experience with foam rolling, the participants across studies presented with varying body masses. The average participant body mass ranged from 69.3 kg in the Richman et al² study to 93.5 kg in the Smith et al⁶ study. Previous research has shown that the amount of pressure applied during foam rolling may be related to the effectiveness of the treatment.² Body mass has also been shown to be related to athletic performance, with body mass being inversely related to athletic performance.¹ Therefore, the wide range of average body mass across studies may explain some of the differences in results. Furthermore, the differences in foam rolling application between studies should be considered. Peacock et al¹ and Richman et al² used a duration of 30 seconds per muscle group during the foam rolling sessions, while Smith et al⁶ used a duration of 90 seconds (3 set of 30 s) and D'Amico and Gillis⁹ used a duration of 60 seconds. While these application times are similar, these differences may explain the differing results between studies. Previous research has suggested that a dose effect is present in the application of self-myofascial release, with greater treatment times yielding greater myofascial release, and therefore greater increases in range of motion.¹⁴

A final limitation of this critically appraised topic is that only one of the included studies induced exercise-induced muscle soreness.⁹ Thus, their results cannot be directly compared with the results of the other included studies that investigated healthy participants with no muscle soreness. Delayed onset muscle soreness has been shown to have negative consequences on athletic performance, including decreased range of motion and power.^{5,15} Although D'Amico and Gillis⁹ found that the addition of foam rolling to a dynamic warm-up attenuates the effect of muscle soreness on agility, this is different than the increase in agility that was found in participants without muscle soreness in the Peacock et al¹ study. These results cannot be directly compared because foam rolling may be working on different mechanisms, that is, inflammation caused by muscle damage,⁵ when an individual is experiencing muscle soreness compared with when one is using foam rolling without the presence of muscle soreness/damage.

The current evidence suggests that the inclusion of foam rolling in a dynamic warm-up may benefit an individual's ability to acutely increase power and agility more than after completing a dynamic warm-up alone. This combination warm-up may demonstrate increased benefit due to the added physiological mechanisms of foam rolling, including enhanced muscle elasticity and neurological feedback² as well as increased blood flow to the skin and muscles.¹⁶ These mechanisms may explain the improvements

Table 2 Characteristics of Included Studies

Study Characteristics	Richman et al ²	Peacock et al ¹	Smith et al ⁶	D'Amico and Gillis ⁹
Study design	RCT with crossover design	RCT with crossover design	RCT with crossover design	RCT
Participants	14 healthy female NCAA Division II volleyball or basketball athletes (mean age = 19.8 [1.3] y). All participants had previous history of significant injury.	11 healthy professional, NCAA Division I, and NCAA Division II male athletes (football, baseball, soccer, track and field; mean age = 22.2 [2.2] y).	29 healthy male and female participants (mean age = 22.0 [3.0] y); 23 of the participants were physically active while 6 were sedentary during the study period.	37 healthy male college students with exercise-induced muscle soreness (mean age = 22.8 [2.6] y)
Intervention investigated	Foam rolling + dynamic stretching: 5-min jogging warm-up followed by foam rolling protocol. Protocol included self-myofascial release of hip flexors/quadriceps, adductors, tensor fasciae latae/gluteals, hamstrings, plantar flexors, and dorsiflexors (30 s per muscle group; 5 min total). Dynamic stretching protocol consisted of 5 min of skipping, knee raises, side-to-side leg loosening, and leg swings. Light walking + dynamic stretching: 5-min jogging warm-up followed by 5 min of self-selected walking pace. Dynamic stretching protocol consisted of 5 min of skipping, knee raises, side-to-side leg loosening, and leg swings.	Dynamic stretching: 5-min jogging warm-up followed by a dynamic stretching protocol including arm circles, squats, squat jumps, sprinting high knees, sprinting butt kicks, alternating lunge jumps, alternating long jumps, scapular push-ups, thoracic rotations, and clapping push-ups (2 × 10, each exercise). Foam rolling + dynamic stretching: 5-min jogging warm-up followed by the foam rolling protocol consisting of massage over the thoracic/lumbar region, gluteus maximus/medius/minimus, hamstrings, hip flexors/quadriceps, plantar flexors, and pectoral region (30 s per muscle group). Foam rolling was followed by the dynamic stretching protocol explained above.	Control: 5-min cycling warm-up followed by 22-min rest. Foam rolling: 5-min cycling warm-up followed by foam rolling protocol. Protocol included massage of quadriceps, hamstrings, gluteals, and plantar flexors (3 × 30 s per muscle group). Dynamic stretching: 5-min cycling warm-up followed by dynamic stretching protocol. Protocol consisted of high knee walking, walking straight leg swings, walking butt kicks, and heel-to-toe walking (4 × 20 m/leg). Foam rolling + dynamic stretching: 5-min cycling warm-up followed by the foam rolling protocol then the dynamic stretching protocol.	Week 1: Training for protocols and baseline measurements (3 d) Week 2, day 1: • Sprinting protocol to induce muscle soreness • Foam rolling group completed foam rolling protocol • Control group rested Week 2, days 2–5: • Foam rolling group completed dynamic stretching warm-up protocol followed by foam rolling protocol • Control group completed dynamic stretching warm-up protocol Foam rolling: Protocol consisted of massage over the quadriceps, hamstrings, gluteus maximus, and gastrocnemius (2 × 60 s per muscle group). Dynamic stretching: Protocol consisted of 50 jumping jacks, 30 high knees, 10 push-ups, and 10 squats. Goniometry for active hip flexion and hip abduction, squat jump, agility <i>t</i> test, PainTest FPM 100 Algometer (Wagner Instruments, Greenwich, CT), and gLMS for soreness.
Outcome measures	Sit-and-reach, squat jump, countermovement jump, drop jump, agility <i>t</i> test, and 10-yard sprint.	Sit-and-reach, countermovement jump, standing long jump, pro-agility test, 1RM bench press, and 37-m sprint.	Sit-and-reach and countermovement jump.	
Main findings	Flexibility significantly increased in the foam rolling plus dynamic stretching group after the addition of foam rolling (TP1 = 37.6 [4.2], TP2 = 39.4 [4.4]; $P = .002$). Flexibility also significantly improved over time in the light walking plus dynamic stretching group (TP1 = 36.3 [4.8], TP3 = 38.5 [4.4]; $P = .008$). However, the percent change between both groups was not significantly different ($P = .942$). Significant differences were found between intervention groups for the squat jump (1.72 [2.47] cm, $P = .022$) and countermovement jump (2.63 [3.74] cm, $P = .021$). No significant differences were found between groups for the agility <i>t</i> test or 10-yard sprint.	Regarding flexibility, no significant differences were found between the dynamic stretching alone group and the foam rolling plus dynamic stretching group ($P = .833$). The foam rolling plus dynamic stretching group performed significantly better than the dynamic stretching alone group for both countermovement jump (72.97 [10.60] vs 67.66 [9.79], respectively; $P = .012$) and standing long jump (237.84 [25.45] vs 228.60 [25.25], respectively; $P = .007$). In addition, the foam rolling plus dynamic stretching group performed significantly better during the pro-agility test ($P = .001$) compared with the dynamic stretching alone group.	For sit-and-reach measurements, the foam rolling alone group had a greater percent change compared with the control group immediately following treatment (7.0% [5.7%] vs 1.9% [5.1%], respectively; $P = .003$). For countermovement jump, the dynamic stretching alone group performed significantly better than control group immediately ($P < .01$) and 5-min post-treatment ($P < .01$). The foam rolling plus dynamic stretching group also performed significantly better compared with control immediately ($P < .001$), 5-min posttreatment ($P < .001$), and 15-min posttreatment ($P = .002$). No significant differences were found between interventions.	Regarding flexibility, no significant differences were found between the control and foam rolling groups ($P > .05$). Similarly, no significant differences were seen between groups during the squat jump test ($P > .05$). The only significant finding was in the agility <i>t</i> test. Participants in the foam rolling group presented with significantly less impairment while completing the agility <i>t</i> test compared with the control group ($P = .0049$).

(continued)

Table 2 (continued)

Study Characteristics	Richman et al ²	Peacock et al ¹	Smith et al ⁶	D'Amico and Gillis ⁹
CEBM level of evidence	2	2	2	2
Validity score	6/10 on PEDro scale	5/10 on PEDro scale	6/10 on PEDro scale	6/10 on PEDro scale
Conclusion	In a healthy population, the inclusion of foam rolling in a dynamic warm-up increased flexibility, but not significantly more than or different from when dynamic stretching was added to light walking. The addition of foam rolling to dynamic stretching was shown to increase vertical jump height more so than the addition of light walking to dynamic stretching. Finally, the addition of foam rolling to dynamic stretching showed no significant improvement in agility. Therefore, the inclusion of foam rolling may benefit power performance but it does not seem to further increase agility or flexibility greater than a dynamic warm-up.	In a healthy population, the addition of foam rolling to a dynamic warm-up did not significantly alter participant flexibility when compared with dynamic stretching alone. However, this inclusion improved vertical jump, long jump, and agility performance compared with a dynamic warm-up alone. Therefore, foam rolling may be a beneficial addition to an athlete's/active person's warm-up routine to improve power and agility performance.	In a healthy population, foam rolling alone was shown to increase flexibility immediately following treatment; however, the acute effects were not long lasting. Foam rolling combined with dynamic stretching produced significant improvements in athletic performance up to 15-min posttreatment. However, these results were not significantly better than the dynamic stretching alone group. Adding foam rolling to a dynamic warm-up may improve performance when compared with doing nothing at all; however, it may not be more beneficial than completing a dynamic warm-up alone.	As a treatment method for exercise-induced muscle damage, no differences were seen between the foam rolling and dynamic stretching groups on vertical jump or flexibility. However, foam rolling was shown to mediate the effects of muscle soreness on agility compared with the control group. Therefore, the inclusion of foam rolling may benefit athletes/active individuals completing high agility sport/activity but may not have much effect on other types of performance when experiencing muscle soreness.

Abbreviations: gLMS, general labeled magnitude scale; NCAA, National Collegiate Athletic Association; RCTs, randomized control trial; TP1, time point 1; TP2, time point 2; TP3, time point 3; IRM, 1-repetition maximum.

in agility noted by Peacock et al¹ and D'Amico and Gillis.⁹ Furthermore, D'Amico and Gillis⁹ study was the only one to look at the effect of foam rolling in a population with exercise-induced muscle soreness. Because this study found slightly different results than the others, their results suggest that foam rolling may have different physiological effects depending on whether an individual is experiencing muscle soreness. More high-quality research using individuals with exercise-induced muscle soreness is needed to establish the acute, as well as long-term effectiveness of including foam rolling in an athlete's warm-up protocol.

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