The Effects of Foam Roller Density on Flexibility Enhancement and Muscle Characteristics on the Quadricep and Calf Muscles

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Background

Flexibility, defined as the range of motion (ROM) achievable without injury (Pate et al., 2012) or undue stress on musculotendinous units (Medeiros & Martini, 2018), is influenced by age, activity level, muscle elasticity, and tone (Behm, 2024). It plays a critical role in sports by enhancing performance (e.g. speed, agility, and power), reducing injury risk, and aiding rehabilitation (Konrad et al., 2021). Key muscle properties like retention (maintaining mass/function), stiffness (resistance to stretching), and tone (readiness for action) directly impact movement efficiency and injury prevention. Managing these properties through strategies like foam rolling (FR) may optimize muscle function (Konrad et al., 2019; Nakamura et al., 2021).

Foam rolling, a self-myofascial release (SMR) technique, uses tools of varying densities to reduce stiffness, alleviate soreness, and improve recovery by targeting soft-tissue adhesions and increasing blood flow (Zhang et al., 2020; Wiewelhove et al., 2019). However, the impact of foam roller densities on acute flexibility remains understudied, and the mechanisms behind SMR's benefits lack robust evidence (Su et al., 2017; Ferreira et al., 2022). This study addresses these gaps to inform evidence-based training and recovery protocols.

Results

SDFR Comparison of Time in Ankle ROM intervention

Comparison	Mean Difference	Standard Error (SE)	95% CI (Lower-Upper)	p-value
Baseline vs Immediate	-2.422*	0.68	[-4.4, -3.8]	0.010
Baseline vs 15 minute	-1.537	0.67	[-3.5,0.45]	0.272
Baseline vs 30 minute	-2.007	0.72	[-4.1,0.14]	0.084
Baseline vs 45 minute	-1.35D	0.79	[-3.7,1]	0.976

Note: Abbreviations; SE= Standard Error, MD= Mean Difference CI= Confidence Interval; Bonferroni adjustment for multiple comparison; Significant at p-value <0.05

HDFR Comparison of Time in Ankle ROM intervention

Comparison	Mean Difference	Standard Error (SE)	95% CI (Lower-Upper)	p-value
Baseline vs Immediate	-2.737*	0.68	[-4.7, -0.7]	0.003
Baseline vs 15 minute	-1.364	0.67	[-3.3, 0.6]	0.489
Baseline vs 30 minute	-1.897	0.72	[-4, 0.2]	0.124
Baseline vs 45 minute	-1.515	0.79	[-3.8, 0.8]	0.640

Note: Abbreviations; SE= Standard Error, MD= Mean Difference CI= Confidence Interval; Bonferroni adjustment for multiple comparison; Significant at p-value <0.05

SDFR Comparison of Time in MTH ROM intervention

Comparison	MD	SE	95% CI	p-value
Baseline vs Immediate	-4.547*	1.50	[-8.9, -.120]	0.040
Baseline vs 15 minute	-3.629	1.55	[-8.2, .950]	0.238
Baseline vs 30 minute	-3.650	1.53	[-8.16, .869]	0.214
Baseline vs 45 minute	-.707	2.61	[-8.4, 6.99]	1.000

Note: Abbreviations; SE= Standard Error, MD= Mean Difference CI= Confidence Interval; Bonferroni adjustment for multiple comparison; Significant at p-value <0.05

HDFR Comparison of Time in MTH ROM intervention

Comparison	MD	SE	95% CI	p-value
Baseline vs Immediate	-3.971	1.50	[-8.3, 0.4]	0.112
Baseline vs 15 minute	-5.094*	1.55	[-9.6, -0.5]	0.020
Baseline vs 30 minute	-3.542	1.53	[-8, 0.9]	0.254
Baseline vs 45 minute	-4.076	2.61	[-11, 3.6]	1.000

Note: Abbreviations; SE= Standard Error, MD= Mean Difference CI= Confidence Interval; Bonferroni adjustment for multiple comparison; Significant at p-value <0.05

SDFR Comparison of Time in Medial Gastrocnemius intervention

Comparison	MD	SE	95% CI	p-value
Baseline vs Immediate	14.931*	4.3	[2.1, 27]	0.013
Baseline vs 15 minute	16.667*	5.4	[0.71, 32]	0.035
Baseline vs 30 minute	12.694	5.1	[-2.5, 27]	0.180
Baseline vs 45 minute	14.167	5.2	[-1.3, 29]	0.098

Note: Abbreviations; SE= Standard Error, MD= Mean Difference CI= Confidence Interval; Bonferroni adjustment for multiple comparison; Significant at p-value <0.05

SDFR Comparison of Time in Lateral Gastrocnemius intervention

Comparison	MD	SE	95% CI	p-value
Baseline vs Immediate	18.667*	5.05	[3.7, 33]	0.006
Baseline vs 15 minute	14.417	5.84	[-2.8, 31]	0.174
Baseline vs 30 minute	16.958*	5.12	[1.8, 32]	0.018
Baseline vs 45 minute	16.542*	5.38	[0.6, 32]	0.036

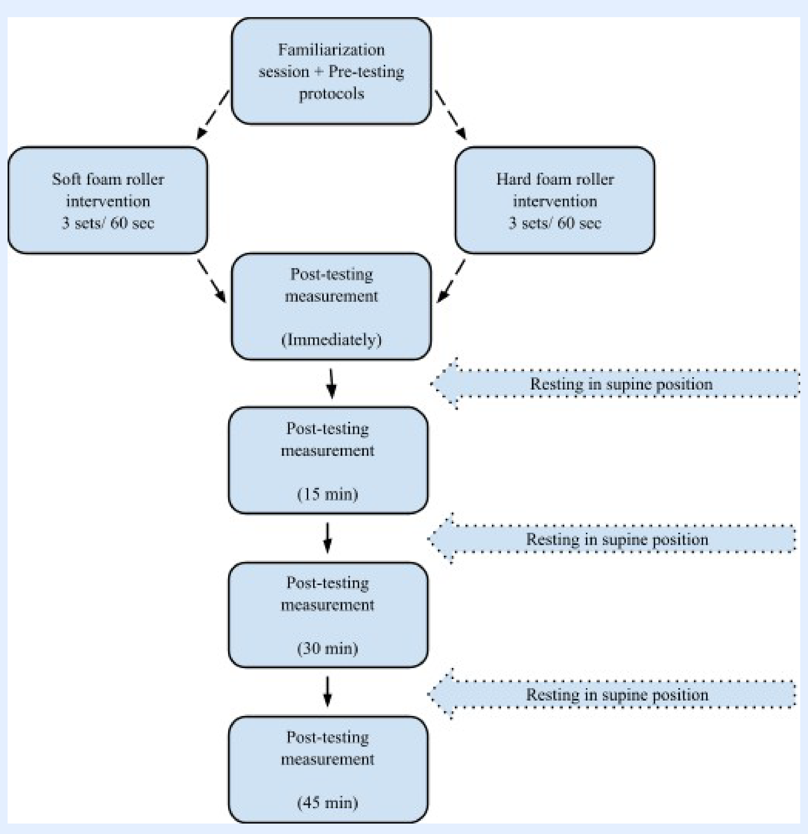
Note: Abbreviations; SE= Standard Error, MD= Mean Difference CI= Confidence Interval; Bonferroni adjustment for multiple comparison; Significant at p-value <0.05

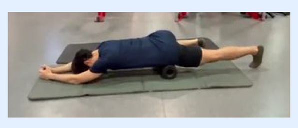
Purpose

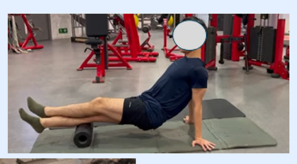
This study investigates how foam roller densities (soft vs. hard) acutely affect flexibility, muscle stiffness, and ROM duration enhancement in the quadriceps and calf muscles.

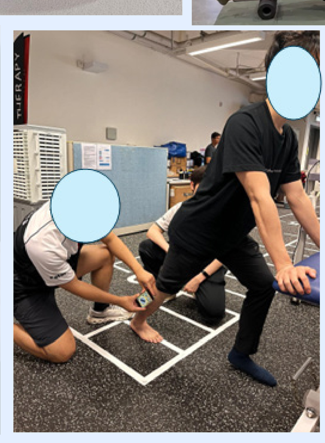
Methodology

- Randomized pre-test/post-test trial comparing soft (19.5A) vs. hard (43A) foam rollers.
- Measurements taken at baseline, immediately post-intervention, and at 15, 30, and 45 minutes.
- 48 healthy adults (18–64 years) with prior foam-rolling experience.
- 3 sets × 60 seconds per muscle (quadriceps/calf) at 20 beats per minute (metronome-guided).
- Standardized rolling motion (proximal to distal) with 30-second rests between sets.









Discussion

- This study concluded that both densities of foam roller (soft and hard) induce an acute increase in lower limb range of motion (ROM), a finding that matches previous literature (Nakamura et al., 2021). The effects of both foam rollers on flexibility were equal with regard to magnitude and duration, supporting previous systematic reviews (Wilke et al., 2019).
- The soft roller offered a significant decrease in calf muscle stiffness (medial and lateral gastrocnemius) whereas the hard roller showed no such effect. This finding goes against the assumption that a greater amount of pressure gives larger tissue changes (Baumgart et al., 2019) and thus suggests that neural mechanisms may have some overriding influence, perhaps through decreased guarding with softer pressure (Kerautret et al., 2021). No significant changes were observed in rectus femoris stiffness, a change which might be expected for larger muscle groups (Konrad et al., 2022).
- Despite flexibility improvements being transient (generally disappearing within 15 to 30 minutes) (Nakamura et al., 2021), a decrease in stiffness through the soft roller was recorded for longer on the lateral gastrocnemius (up to 45 minutes), which may imply that differences exist between the mechanisms or existence of effects when compared with flexibility changes (Ingram et al., 2025; Garcia-Bernal et al., 2021).

Limitations:

- Study examined only acute effects from a single session.
- Did not analyze the influence of individual factors (age, gender, BMI, fitness).
- Applied pressure was not measured.
- Findings are limited to healthy individuals familiar with foam rolling.

Future Research:

1. Explore the interaction of individual characteristics and applied pressure with roller density effects.
2. Investigate the underlying neural mechanisms using simultaneous measurements.
3. Examine a wider range of densities, textures, durations, and the cumulative effects of regular use.

Practical Application

For greater adaptability, both soft and hard rollers are applicable; so the choice is comfort-dependent. For the acute reduction of calf stiffness, soft rollers are the best. For flexibility, roll just before activity, or for stiffness, roll nearer to activity or during recovery. The effects are specific to the muscle; big muscles such as quadriceps may not show changes in stiffness. When reduction of stiffness is desired, go for comfort and less intense pressure. So, choose the rollers and pressure according to your tolerance levels. The ability of soft rollers to decrease calf stiffness might be beneficial in rehabilitation.

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