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Original Research

Effectiveness of a Foam Roller Warm-Up in Professional Basketball Players: A Randomized Controlled Trial

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Background

The foam roller is considered a versatile tool. Along with an active warm-up, it appears to positively affect range of motion, stability, muscle stiffness, and perceived exertion with no reductions in performance.

Hypothesis/Purpose

The main purpose of the study was to observe the effects of the utilization of a foam roller during the warm-up on ankle mobility and lower limb stability, and secondarily, to assess if any induced effects were sustained over time.

Study design

Randomized controlled trial.

Methods

Twenty-two healthy male subjects were randomly assigned to two groups: the control group, which only carried out a general warm-up over a period of four months, and the foam roller group, which followed a specific warm-up routine using a foam roller for a period of three months plus one month of follow-up in which no foam rolling was performed. Two outcome measurements were taken pre- and post- intervention to assess ankle mobility: the Dorsi-Flexion Lunge test and the Y-Balance test (YBT) for the lower quarter. Outcomes were measured at three time points: before the protocol was initiated, at the end of the protocol (at 12 weeks), and after a one-month follow-up period (at 16 weeks).

Results

A significant increase was observed in the dorsiflexion of the right ($p < 0.001$) and left ($p < 0.001$) ankles in the experimental group. Significant increases were also noticed in the anterior ($p < 0.003$), posteromedial ($p < 0.050$), and posterolateral ($p < 0.050$) reach distances of the right leg and in the anterior ($p < 0.002$), posteromedial ($p < 0.010$), and posterolateral ($p < 0.030$) reach distances of the left leg during the YBT in the experimental group. The control group also showed significant differences in the right ($p < 0.007$) and left ($p < 0.010$) anterior reach distances on the YBT. At the one-month follow-up period, the improvements that had been obtained in both groups were lost, except for the dorsiflexion of the right ankle ($p < 0.050$) and right ($p < 0.010$) and left ($p < 0.030$) anterior reach distance on the YBT in the experimental group.

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Conclusions

The foam roller can be used as a part of a pre-training warm-up routine to enhance the dorsiflexion range of motion and performance on the YBT.

Level of Evidence

3. Registered as a clinical trial at ClinicalTrials.gov with registration number: NCT05971316.

INTRODUCTION

A "warm-up" is defined as a period of exercise that precedes the physical activity or sports practice, and the intention is to gradually adapt the body both physically and mentally.[1] This process improves neuromuscular performance, reduces the risk of injuries during the sport activity,[2] and is essential to achieve optimal performance. Regarding the physiological mechanisms that are responsible for the effects of warm-up,[3] both active[4,5] and passive[6] warm-up have been shown to result in an increase in the range of movement (ROM)[7] and a reduction in muscle stiffness.[8,9] These beneficial effects can be attributed to an increase in the rate of metabolic chemical reactions and muscle temperature, alterations in viscoelastic and thixotropic properties, and an enhanced sensitivity of the nerve receptors in the muscle.[10] Furthermore, the increase in the elasticity of muscle fibers that follows the warm-up period enhances the muscle's capacity to absorb energy within the muscle-tendon unit, thereby supporting an increase in tension and preventing injuries to muscle and tendon fibers.[5] The most recent research on the efficacy of various warm-up methods, both active and passive, indicates that a general warm-up and a sport-specific warm-up are recommended in team sports such as soccer, basketball, handball and rugby, amongst others.[11] However, since the sport-specific warm-up is primarily based on trial and error, identifying the most effective warm-up methods for each sport can prove challenging.[12]

The foam roller (FR) has been identified as a potentially beneficial tool for use as part of a warm-up routine to exercise or pre-competition,[13] both in amateur and professional athletes. The primary objective of incorporating the FR into a warm-up routine is to enhance athletic performance.[14-16] The FR technique involves the athlete using a roller, typically made of high- to medium-density foam, to apply a direct pressure to a specific muscle group.[17] The use of the FR has been demonstrated to have a wide range of beneficial effects, including an increase in flexibility,[9] improved muscle recovery,[18,19] reduced soft tissue adhesion, decrease in delayed-onset muscle soreness,[20] modulation of the nervous system function,[21] enhanced vascular response,[22,23] increased ROM,[7] and improved muscle performance before and after exercise.[24,25] In contrast, meta-analytic evidence on lower limb performance in parameters related to strength, speed, and jump height continues to show controversial data on a significant improvement when a FR routine is applied.[26]

At the present time, there is no standardized FR application protocol. However, recent studies have provided some notable guidelines. For instance, the use of FR in combination with an active warm-up before a training session has been shown to be more effective in improving ROM and flexibility.[27] When combined with other techniques, such as dynamic stretching or cycling, significant improvements have been observed.[5,9,13] The minimum application time to induce physiological changes appears to be 90 seconds, as reported in several series.[28] Additionally, the athlete's experience with this tool[29] and the possibility of rolling at higher speed[30] should be taken into account, as they may contribute to a more pronounced decrease in tissue stiffness.

The sport of basketball is defined by a series of continuous movements, which include sprints, changes of direction, and high-impact jumps. These actions underscore the significance of both aerobic and anaerobic physical capacities, as well as lower limb strength, agility, and ROM. Limitations of ROM have been demonstrated to be a main predictor of lower limb injuries,[31] and consequently, are a crucial element in the reduction of the risk of injury and the optimization of the athletic performance.[32] Within the context of basketball, lateral ankle sprains represent a particularly prevalent musculoskeletal injury.[33] The primary underlying cause may be attributed to a limitation of ankle dorsiflexion ROM, which affects the biomechanics of the foot[34] and of running and landing, alters balance, and increases the risk of injury to more proximal joints such as the knee or the hip.[35,36] Foam rolling has demonstrated a significant impact on ROM, not only in the dorsiflexion of the ankle,[28,37-40] but also in the knee[7,18,25] and hip.[41,42] It has been shown that ankle dorsiflexion is intimately connected to lower limb balance. A reduction in ankle dorsiflexion has been linked to a decline in lower limb balance, whereas an increase in ankle dorsiflexion has been associated with an enhanced lower limb balance.[33] The FR can be used as an unstable surface and presents a challenge to maintain the stability and balance of to the body. Use of body weight and postures during rolling may be associated with secondary effects on core stability.[43]

This is the first study to examine the impact of FR as a component of the warm-up routine in professional basketball players over a three-month period of time. The main purpose of the study was to observe the effects of the utilization of a foam roller during the warm-up on ankle mobility and lower limb stability, and secondarily, to assess if any induced effects were sustained over time.

MATERIALS AND METHODS

PARTICIPANTS

A randomized controlled study with two parallel groups was carried out. The sample for this study of healthy male professional basketball players was recruited from the Spanish national division and had to be between 19 and 29 years of age. In order to be included in the study, participants were required to meet several criteria. These included engaging in a minimum of three training sessions per week, participating in weekend competitions, having prior experience in the use of a FR, not having sustained significant musculoskeletal injuries or undergone surgery in the lower limbs within the year preceding the study, and not having a diagnosed orthopedic or neurological pathology in the lower limbs. Injuries that impeded compliance with the prescribed minimum training sessions per week or the established warm-up routine lead to exclusion. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Catholic University San Antonio of Murcia (UCAM) (reference no.: CE052314, ClinicalTrials.gov registration number: NCT05971316). Informed consent was obtained from all the subjects involved in the study.

The 24 participants were randomly assigned to two study groups using the GraphPad Software (https://www.graphpad.com/quickcalcs/randomize1/). The control group (CG) consisted of 12 participants who underwent a general basketball warm-up. The experimental group, the foam roller group (FRG), consisted of 12 participants who performed a foam roller warm-up (FRWU), which added to the general warm-up performed by the CG.

PROCEDURE

There were three data collection timepoints for both groups. Initial pre-FRWU measurement (T0, week 0) was conducted. Subsequently, FRG participants were instructed on the FRWU they were to perform over the subsequent three-month period (weeks 1 to 12). In contrast, CG subjects only engaged in a general basketball warm-up, as prescribed by the strength and conditioning coach. This warm-up compromised mobility exercises, ballistic stretches, changes of direction and ball exercises. A second post-FRWU measurement (T1) was conducted at week 12. Following a four-week follow-up period during which neither the FRWU nor the general warm-up was performed for either group, a third post-FRWU measurement (T2, week 16) was conducted (Figure 1).

Prior to the completion of the primary tests, anthropometric data including body mass and height, were obtained. Body mass was determined using a TANITA BC-601 scale (Tanita®, Illinois, USA) with an accuracy of 0.1 kg. Height was assessed with a TANITA HR001 stadiometer (Tanita®, Illinois, USA), with a graduation of 1 mm, a measurement range from 0 to 210 cm, and an accuracy of 0.1 cm. Subsequently, the body mass index (BMI) of each of the participants was calculated (kg/m^2).

TEST 1: ANKLE DORSIFLEXION

In order to assess ankle dorsiflexion, the dorsiflexion lunge test (DLT)[44] was utilized. Data were recorded using the My-Rom app from MyJumpLab for iOS. This method has been fully validated, exhibiting a standard error of estimate of 0.48°, an intraclass correlation coefficient of 0.976, and a coefficient of variation of 5.1 ± 2.3%, which is comparable to the results obtained using a digital inclinometer (coefficient of variation = 4.9 ± 2.5%).[45]

The subject, barefoot and facing a wall, positioned the first toe to be measured on a line marked on the floor at a 15 cm distance from the wall. A strap was utilized to secure the mobile phone at the tibial midline, located 15 cm distal to the tibial tuberosity[44] (Figure 2). Participants were instructed to attempt to contact the wall using their knee, thereby performing a maximal dorsiflexion without lifting the heel off the ground, on three attempts. In the event that the subject contacted the wall during the initial attempt, he was instructed to withdraw his foot from the starting line and to repeat the three attempts. The degrees of both ankles were automatically obtained using the inclinometer of the mobile phone. The same procedure was then repeated for both ankles, and the mean value from the three attempts subsequently utilized for data analysis.

TEST 2: BALANCE

The YBT was selected to assess lower limb stability. This is a valid adaptation of the star excursion balance test (SEBT) that evaluates coordination, balance, flexibility, and lower limb strength, specifically through the anterior reach (AR), posteromedial reach (PMR), and posterolateral reach (PLR) distances. The protocol established by Plisky et al.[46] was utilized employing the Y-Balance Test Kit™ (Functional Movement Systems, Chatham, VA, USA) The YBT intraclass correlation coefficient for intrarater reliability ranges from 0.85 to 0.91, whereas the interrater reliability ranged from 0.99 to 1.00; additionally, composite reach score reliability was 0.91.[47] Subject was positioned in a unipedal, barefoot position, with the leg to be tested situated at the center of the inverted Y test equipment. With the hands firmly placed on the hips, athletes were instructed to slide the block as far as possible with the foot, not lifting the heel, and return to the initial upright position. Once three successful reaches had been achieved, athletes went on to the next foot. The order of performance was as follows: right AR, left AR, right PMR, left PMR, right PLR, and left PLR (Figure 3). For the purpose of data analysis, relative distance was employed. This was defined as the percentage obtained by dividing the absolute reach distance achieved in each of the directions by the limb length to be evaluated and multiplying the result by 100.

FOAM ROLLER ROUTINE: FOAM ROLLER WARM-UP

FRWU was conducted exclusively by subjects of the FRG for a period of three months, prior to their training sessions and in combination with the general warm-up routine prescribed by the strength and conditioning coach. In contrast,

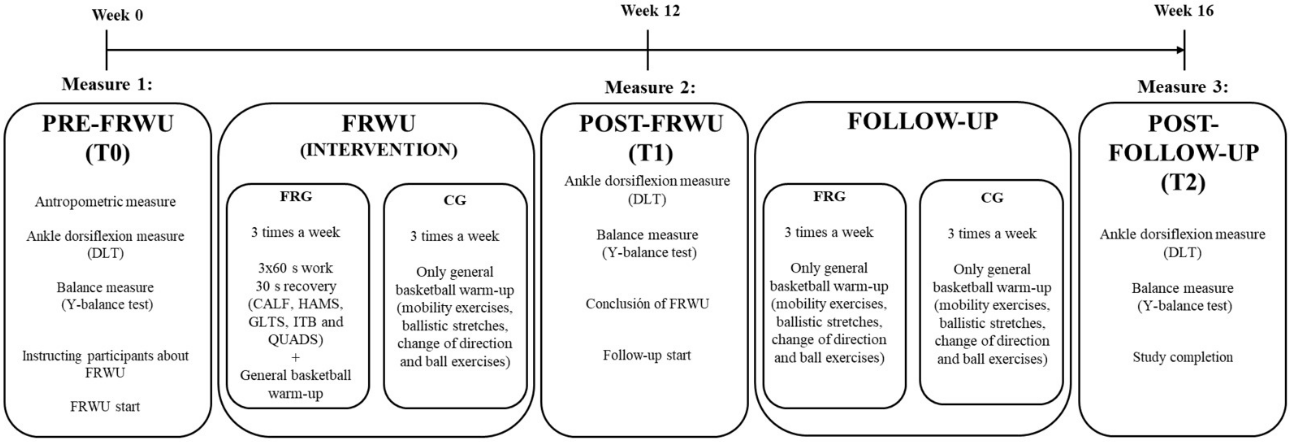

Figure 1. Flow chart of the experimental design.

Note: FRWU: foam roller warm-up; FRG: foam roller group; CG: control group; DLT: dorsiflexion lunge test; HAMS: hamstrings; GLTS: gluteal muscles; ITB: iliotibial band; QUADS: quadriceps.

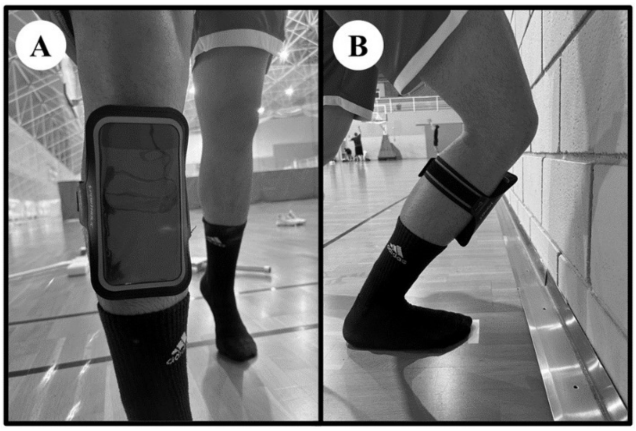

Figure 2. Frontal (A) and lateral (B) views of the dorsiflexion lunge test.

participants or the CG only performed a general warm-up routine that was identical to the one that was carried out by the experimental group, and which included mobility exercises, ballistic stretching, changes of direction and ball exercises.

FRWU was designed with a special focus on the lower limb musculature and was developed based on adaptations from previous studies.[39,48,49] Participants were instructed to perform three sets of 60 seconds of work with a 30 second rest period between sets, three times per week (during training sessions), using a smooth, high-density foam roller (33 centimeters long and with a diameter or 13 centimeters), which is commonly available on the market. Exercises were bilateral for calf muscles, hamstrings, quadriceps, and gluteal muscles, and unilateral for the iliotibial band. Participants only applied their body weight with a moderate pressure ranging a self-report of between 5 and 7 on a numerical subjective scale (where 0 represents the absence of discomfort and 10 represents the maximum level of discomfort), and they avoided muscle spasms or cramps.[50]

For each segment of the lower limb, participants rolled the foam roller in a continuous motion from the top to the bottom of the muscle or muscle group, returning to the starting position at the conclusion of the movement.

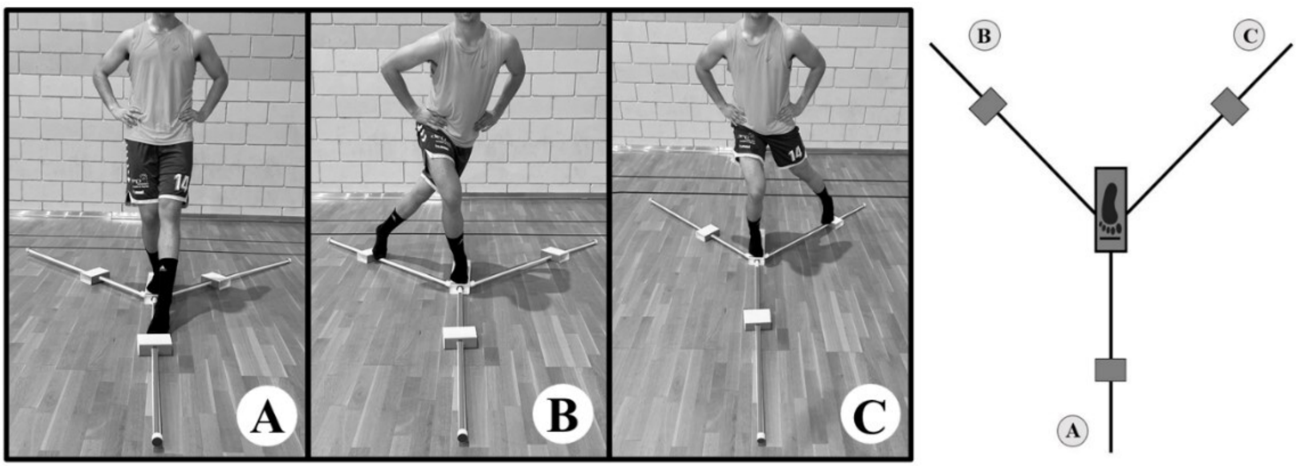

Figure 3. YBT anterior reach (A), posterolateral reach (B) and posteromedial reach (C).

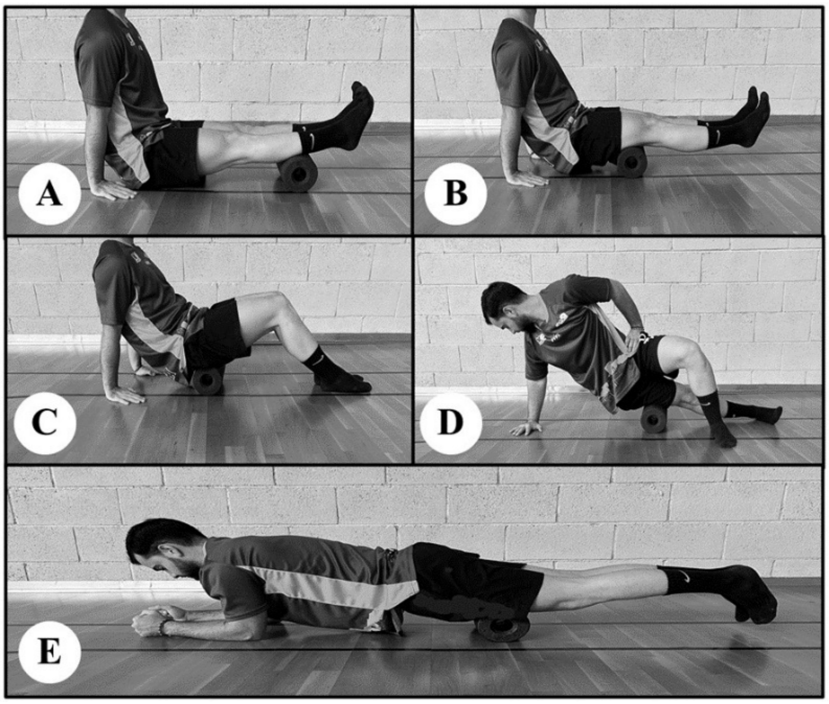

Figure 4. Foam roller warm-up protocol for the calves (A), hamstrings (B), gluteal muscles (C), ITB (D), and quadriceps (E).

For hamstrings, calves, and gluteal muscles, participants adapted a seated position with the roller positioned beneath the targeted muscle group, with the legs elevated for the hamstrings and calves and supported for the glutes. Hands were placed on the ground with fingers pointing toward the body, thereby supporting a portion of the participants' body weight. In the case of the quadriceps, subjects assumed a prone position, with forearms on the ground in a plank position, and the foam roller was positioned under their thighs. Finally, for the iliotibial band, participants assumed a lateral position, with one leg crossed in front of the other and the bottom leg slightly elevated off the ground (Figure 4).

STATISTICAL ANALYSIS

All data were stored in a database that had been specifically designed for this study. A review was conducted to identify any inaccurate data entries or extreme outliers, i.e., data that were considered not to be representative of the study variables and none were found. All descriptive and inferential statistical analyses were performed using various libraries within the RStudio advanced statistical processing program.[51] An independent sample t-test was used to assess for significant differences between the two groups. Paired t-tests were used to assess the mean difference before and after the intervention and to assess if significant differences had occurred. Data normality was examined through the Shapiro-Wilk test. In cases where these assumptions were not met, a non-parametric equivalent test was employed, such as the Wilcoxon signed-rank test. Significance level was set at $p < 0.05$ for all of the tests.

Moreover, to describe the magnitude of the difference or the relationship between the means of two paired groups, the effect sizes were calculated using the Cohen's d which provides an indication of the practical significance, or the strength of observed the relationship, which is independent of the sample size. Finally, to calculate the study power, a *post-hoc* analysis was performed using the results obtained through the G*Power program.[52] A significance level of $\alpha < 0.05$ was established, employing a one-tailed test, as improvement was obtained, and a large effect size was assumed for the variables of interest in the study.

RESULTS

Twenty-four subjects were recruited and enrolled in the study. Subsequently, two subjects were excluded from the study due to an injury and their inability to comply with the routine, resulting in a final study sample of 22 participants. (Table 1). There were no statistically significant differences between the groups.

ANKLE DORSIFLEXION

The comparison of the ankle dorsiflexion means between both groups at the three measurement points revealed no statistically significant differences. Both groups exhibited non-significantly different values at T0 (pre-FRWU) (for the FRG: $p = 0.355$; and for the CG: $p = 0.227$). Whereas at T1 (post-FRWU), the FRG ($p = 0.092$) displayed higher mean values than the CG ($p = 0.379$), again without significant differences. Results were not statistically significant, with the FRG ($p = 0.583$) mean being lower than that of the CG ($p = 0.086$). (Table 2).

Table 1. Participant characteristics. Values are reported as mean and standard deviation (SD).

	FRG	CG	TOTAL	p-value
Participants, *n*	11	11	22	
Age, years	23.7 (4.5)	22.2 (4.7)	23.0 (4.6)	0.3439[a]
Body mass, kg	77.5 (13.0)	85.4 (20.5)	81.4 (17.2)	0.2901[b]
Height, cm	180 (0.1)	180 (0.1)	180 (0.1)	0.6387[b]
Body mass index, kg/m^2	24.7 (4.3)	26.1 (2.8)	25.4 (3.6)	0.3815[b]

FRG: foam roller group; CG: control group. [a]Wilcoxon rank sum test. [b]Two sample t-test.

Table 2. Ankle dorsiflexion means for the foam roller group and the control group over time. All are reported in degrees.

	FRG			CG		
	T0	T1	T2	T0	T1	T2
Left	46.3 (7.0)	52.8 (8.1)	47.4 (5.0)	46.2 (5.6)	49.2 (7.0)	51.1 (5.5)
Right	45.7 (3.9)	52.7 (7.1)	48.9 (5.9)	46.0 (7.33)	47.7 (8.8)	49.1 (7.2)

Values are represented in terms of the mean and standard deviation (SD). FRG: foam roller group; CG: control group.

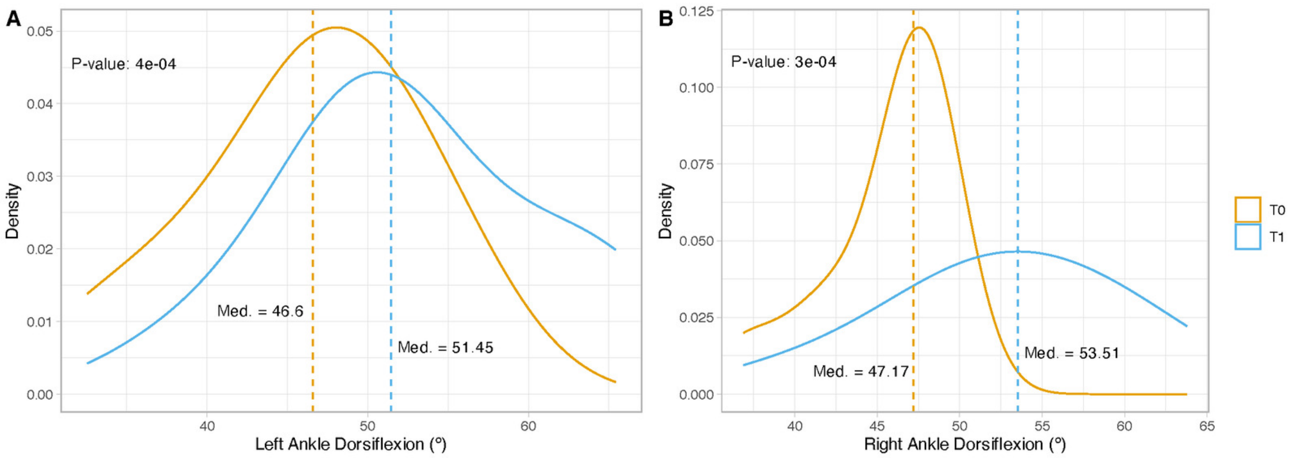

Figure 5. Comparison of medians in ankle dorsiflexion between T0 and T1 in the FRG. Med.: median; density: proportion of individuals.

A significant increase was observed between T0 and T1 between groups for dorsiflexion of both the right (p = 0.001) and left (p = 0.001) ankles, with a large effect size (d ˃ 0.8) observed exclusively in the FRG. However, a significant increase was observed only in the FRG for the ROM of the right ankle (p = 0.041) in the T0-T2 (pre-FRWU to follow-up) comparison, with a medium effect size (d = 0.6). No statistically significant differences were observed in the CG. (Table 3).

Figure 5 presents a comparison of medians exclusively for the FRG between T0 and T1. Left and right ankle dorsiflexion is shown. A shift to the right is observed in both the density curve and the median of both ankles, in the left ankle grades (medT0 = 46.6° versus medT1 = 51.45°; p = 0.149) and in the right ankle grades (medT0 = 47.1° versus medT1 = 53.5°; p=0.336).

BALANCE

A comparison of the means of the YBT outcomes between the two groups at the three measurement points revealed a significant increase in percentage distance only at T1 for the FRG for right PMR (p = 0.003) and left PLR (p = 0.005) and also for the CG for right PMR (p = 0.014) and left PLR (p = 0.024) (Table 4).

A significant increase was observed in all of the YBT distances within the FRG between T0 and T1, exhibiting a large effect size for right (p = 0.003, d = 1.1) and left (p = 0.002, d = 1.3) AR, for right (p = 0.050, d = 1.3) and left (p = 0.010, d = 0.8) PMR, and for right (p = 0.050, d = 0.8) and left (p = 0.030, d = 0.9) PLR. In contrast, CG showed a significant increase only in right (p = 0.007, d = 1.3) and left (p = 0.010, d = 1.2) AR between T0 and T1. With regard to the improvements observed between T0 and T2, a significant increase was identified only in the FRG for right (p =

Table 3. Comparison and intragroup differences in ankle dorsiflexion across different time points, with associated effect sizes. All differences are reported in degrees.

	FRG						CG					
	T0-T1			T0-T2			T0-T1			T0-T2		
	MD	CI 95%	d	MD	CI 95%	d	MD	CI 95%	d	MD	CI 95%	d
Left	6.5*	[3.7,9.3]	0.8 (L)	1.15	[1.1,3.5]	0.1 (N)	2.9	[2.6,8.4]	0.4 (S)	4.9	[0.3,10.0]	0.9 (L)
Right	7.1*	[4.1,10.0]	0.9 (L)	3.28*	[0.9,5.7]	0.6 (M)	1.7	[4.3,7.7]	0.2 (S)	3.1	[0.1,6.1]	0.4 (S)

Cohen's values (d) are indicated as follows: L for large, M for medium, S for small, and N for negligible. MD: mean difference; CI: confidence intervals; FRG: foam roller group; CG: control group. * Statistically significant differences at $p < 0.05$.

0.010, d = 1.3) and left (p = 0.030, d = 1.2) AR, with a large effect sizes (Table 5).

Figure 6 presents a comparison of medians exclusively for FRG between T0 and T1, for all of the distances of the YBT. A shift to the right is observed in the density curve and the median of both lower limbs in left AR (medT0 = 63.73% versus medT1 = 78.43%; p = 0.002), right AR (medT0 = 63.73% versus medT1 = 78.1%; p = 0.003), left PMR (medT0 = 73.64% versus medT1 = 80%; p = 0.015), right PMR (medT0 = 69.09% versus medT1 = 80.87%; p = 0.052), left PLR (medT0 = 73.53% versus medT1 = 84.55%; p = 0.035) and right PLR (medT0 = 73.91% versus medT1 = 83.33%; p = 0.050).

Finally, post-hoc statistical power of 0.84 was achieved, which is the minimum common convention for statistical power required for a study, although the sample was small.

DISCUSSION

Based on the literature review that was conducted, and to the best of the authors' knowledge, this is the first study to evaluate the potential benefits of FR as a component of an active warm-up routine prior to the sport practice over a 12-week period of time, specifically in terms of enhancing ankle mobility and lower limb balance. Furthermore, the study sought to ascertain whether these outcomes were maintained over time, with a four-week follow-up period. The obtained results indicated a significant improvement in the right and left ankle dorsiflexion for the FRG following the FRWU. With regard to the lower limb balance, significant improvements were observed in all of the variables of the YBT for the FRG following the FRWU. However, these improvements were not sustained during the follow-up period for any of the tests. Significant improvements were only observed in the CG in the right and left AR in the YBT.

The observed increase in the ankle dorsiflexion degrees is supported by a substantial body of evidence from previous studies, which demonstrates that foam rolling results in an immediate enhancement of the ROM, not only in the ankle, but also in other joints such as the hip[41,42] and the knee.[18,25,53] Results of the current study indicate that the foam roller group exhibited an increase in the ankle dorsiflexion of 6.5° on the left side and 7.1° on the right after 12 weeks of foam roller warm-up. Prior research has demonstrated that FR can facilitate a 3.4° increase in plantar flexion following its application to the calf, for three sets of 60 seconds on, 30 seconds off, for 4 weeks, every day of the week[37] and a 9° enhancement in acute ankle ROM was seen with a 4.5° increase observed on the dominant leg and a 4.4° increase on the non-dominant leg , following 1 minute of foam rolling to the quadriceps and calf.[38] Additionally, a 7% increase in the ankle ROM after 3 sets of 30 seconds of application and 30 seconds of rest,[39] and an enhancement in the ankle dorsiflexion were both noted without modifying the maximal muscle torque, regardless of the performance of one set, 3 sets or 10 sets of 30 seconds.[28] On the other hand, the implementation of FR over a six-week intervention period has been demonstrated to result in an enhanced ankle ROM and targeted movement patterns during the athletic activities, thereby reducing the risk of injury and enhancing athletic performance.[54] A notable 11% increase in the ankle ROM was observed after five weeks of intervention.[50] Furthermore, incorporating FR into the warm-up for eight weeks resulted in an enhanced ankle ROM without compromising the lower limb stability.[55] The obtained results and a recent review indicate that an FR intervention longer than four weeks and with a minimum of three sessions per week induces a significant effect on gains in the ankle ROM.[56] Therefore, based on the aforementioned studies and the data obtained in this study, the use of the FR on the lower limb as a part of an active warm-up over a long period of time (three months) can be used to improve the ankle dorsiflexion ROM of both ankles. Thus, this is the only study that corroborates the improvements seen and provides evidence that prolonged use of FR is associated with enhanced ankle range of motion.

Currently, there are no published references on the influence of FR on lower limb stability. Hence, this article, makes a novel contribution to the existing literature on the topic. The importance of the improvements in lower limb stability, which appear to be closely related to the improvements in the ankle dorsiflexion ROM, cannot be overstated. Previous authors have demonstrated that a reduction in the ankle dorsiflexion results in a decline in lower limb balance.[33] Additionally, the performance of FR interventions can provide core muscular activation levels that are comparable to or even higher than those achieved with plank exercises.[55] This is because the postures that are applied during the use of FR, such as those adopted for the quadriceps, are similar to the ones that are applied in the plank position. This could exert an enhancing and activating effect on core stability, thus indirectly contributing to improving the lower limb balance as measured by the YBT.[57] The findings of the current study indicate that improvements were observed in all of the lower limb balance parameters, which occurred with enhanced ankle dorsiflexion range ROM in both ankles.

In addition to being a valid method for measuring lower limb balance, the YBT is also considered to be a reliable test for assessing the risk of lower limb injury.[46,58] In a study performed by Engquist et al.,[59] the YBT was administered to university athletes and non-athlete university students, and results demonstrated that the athlete group exhibited a superior performance in the anterior reach (75% better), posteromedial reach (85-90% better), and posterolateral reach (90-95% better) compared to the non-athlete group. Following the application of the FRWU in this study, the mean distances achieved by the FRG nearly reached the benchmarks established by Engquist et al.[59] for all of the reach distances in both legs. Athletes in the current study demonstrated improved reaches which may relate to enhanced sensory integration, enabling optimal responses to diverse motor tasks and offering a potential for reduction of lower extremity injuries.

Following the four-week follow-up period (T2), during which FR was not employed, the enhancements achieved by the FRG exhibited a notable decline, approaching the values observed at T0. This is not surprising as the main

Table 5. Comparison and intragroup differences in lower limb balance across different time points. All values are reported as percentages (normalized to limb length).

	FRG						CG					
	T0-T1			T0-T2			T0-T1			T0-T2		
	MD	CI 95%	d	MD	CI 95%	d	MD	CI 95%	d	MD	CI 95%	d
Right AR	8.6*	[3.6,13.6]	1.1 (L)	12.7*	[2.9,22.5]	1.0 (L)	8.2*	[2.8,13.6]	1.3 (L)	5.5	[6.7,17.6]	0.4 (S)
Right PMR	10.3*	[5.9,16.0]	1.3 (L)	3.6	[3.4,10.7]	0.3 (S)	2.3	[3.5,8.2]	0.3 (S)	2.2	[6.1,10.5]	0.2 (N)
Right PLR	8.3*	[0.1,16.5]	0.8 (L)	6.2	[1.2,14.5]	0.6 (M)	0.9	[5.2,7.2]	0.1 (N)	1.1	[7.4,9.7]	0.1 (N)
Left AR	9.5*	[4.4,14.6]	1.3 (L)	13.2*	[1.4,25.0]	0.9 (L)	9.9*	[2.9,17.0]	1.2 (L)	6.7	[6.6,20.1]	0.4 (S)
Left PMR	7.9*	[1.8,14.0]	0.9 (L)	3.5	[3.2,10.3]	0.3 (S)	3.7	[3.1,10.6]	0.5 (M)	1.9	[7.8,11.6]	0.1 (N)
Left PLR	7.7*	[0.6,14.8]	0.8 (L)	5.2	[4.1,14.6]	0.5 (S)	0.4	[4.4,5.2]	0.1 (N)	1.6	[6.4,9.6]	0.1 (N)

Cohen's values (d) are indicated as follows: L for large, M for medium, S for small, and N for negligible. MD: mean difference; CI: confidence intervals; FRG: foam roller group; CG: control group; AR: anterior reach; PMR: posteromedial reach; PLR: posterolateral reach. *Statistically significant differences at $p < 0.05$.

Table 4. Reach outcomes between the foam roller group and the control group over time. All values are reported as percentages (normalized to limb length).

	FRG			CG		
	T0	T1	T2	T0	T1	T2
Right AR	66.6 (11.7)	75.2 (7.4)	79.4 (15.4)	68.5 (7.5)	76.7 (4.5)	73.9 (17.6)
Right PMR	70.1 (9.1)	81.0 (7.3)*	73.7 (13.1)	72.9 (8.5)	75.3 (4.7)*	70.7 (13.7)
Right PLR	77.6 (11.7)	85.9 (9.0)	84.3 (10.2)	79.7 (9.7)	80.7 (5.7)	80.9 (13.3)
Left AR	66.6 (7.0)	76.1 (7.4)	79.8 (17.5)	68.3 (9.6)	78.2 (6.5)	75.1 (20.0)
Left PMR	73.4 (8.2)	81.3 (8.7)	76.9 (11.9)	73.4 (8.4)	77.2 (5.8)	75.3 (14.9)
Left PLR	77.9 (9.8)	85.6 (8.3)*	83.1 (12.0)	79.4 (7.7)	79.8 (4.6)*	81.0 (12.4)

Values are represented in terms of the mean in percentage and standard deviation (SD). FRG: foam roller group; CG: control group; AR: anterior reach; PMR: posteromedial reach; PLR: posterolateral reach. * Statistically significant differences at $p < 0.05$.

benefits of foam rolling are acute adaptations of soft tissue elasticity, pain threshold, and stretch tolerance.[60] This is a result of the rich sensory innervation of soft tissue, which plays an important role in specific tissue adaptations, including increased skin, muscle, and fascia temperature,[24] improvements in vascular function,[23] and reduced muscle stiffness.[61] Additionally, FR contributes to systemic adaptations, which are related to the inhibition of the mechanoreceptors. These adaptations are thought to result in increased muscle relaxation after approximately fifteen minutes of use.[62] It can be reasonably assumed that the altered perception of pain, which is a result of the sensory stimulation and the acute local systemic response, is the reason for the observed increase in ROM rather than muscle stiffness.[63] Therefore, this would suggest that a FR is suitable tool for use during the warm-up prior to explosive actions due to its acute potential. However, it should be noted that the effects of this technique can affect endurance actions, as improvements are maintained for thirty minutes[40] and then begin to decline drastically after sixty minutes,[64] with values similar to the initial values being observed at three hours.[65] This would underpin the assertion that, after using FR for a period of three consecutive months, discontinuing its application, even for a brief time interval (one month), results in a regression to the initial values observed at the onset of the first three months.

The findings of this study indicate that the regular practice of FR for a minimum of three sessions per week over an extended period of time, with no interruptions, results in an enhancement in ankle dorsiflexion ROM and lower limb balance, which can positively impact the biomechanics of running and landing after jumping, as well as altering the balance of lower extremities.[35] ROM and balance factors are considered to be the main causes of ankle injuries in basketball.[66] As previously hypothesized, alterations in such factors can result in a reduction in the probability of lower extremity injuries by up to 85% and an enhancement in athletic performance.[67]

It must be acknowledged that this study is not without limitations. Firstly, the FR is a relatively novel tool, that presents certain challenges in establishing a standardized protocol for its use. Secondly, the sample size was small, primarily due to the inclusion of professional basketball players who were required to possess proficiency in the use of the FR, which presented a challenge in terms of recruitment. However, adequate post-hoc power was achieved. Thirdly, a follow-up period of an equal duration to that of the intervention would allow for the clarification of whether the observed improvements are maintained over time or diminish rapidly. Due to the small sample size, this work can only be considered to be an exploratory study with the aim of generating new hypotheses that should lead to additional trials. Accordingly, further research with a larger sample size and beyond male basketball players is required to validate these findings.

CONCLUSION

The results of the present study demonstrate the effectiveness of the foam roller as a component of a warm-up routine for male basketball athletes, with a particular emphasis on ankle dorsiflexion and lower limb balance. Enhancement in the degrees of dorsiflexion of both ankles and in all of the distances of the YBT was seen post intervention in the experimental group, after a three-month period of continuous use. The FR could be a valuable tool to incorporate into the pre-training warm-up routine for basketball athletes to improve ankle dorsiflexion and lower limb stability.

CONFLICTS OF INTEREST

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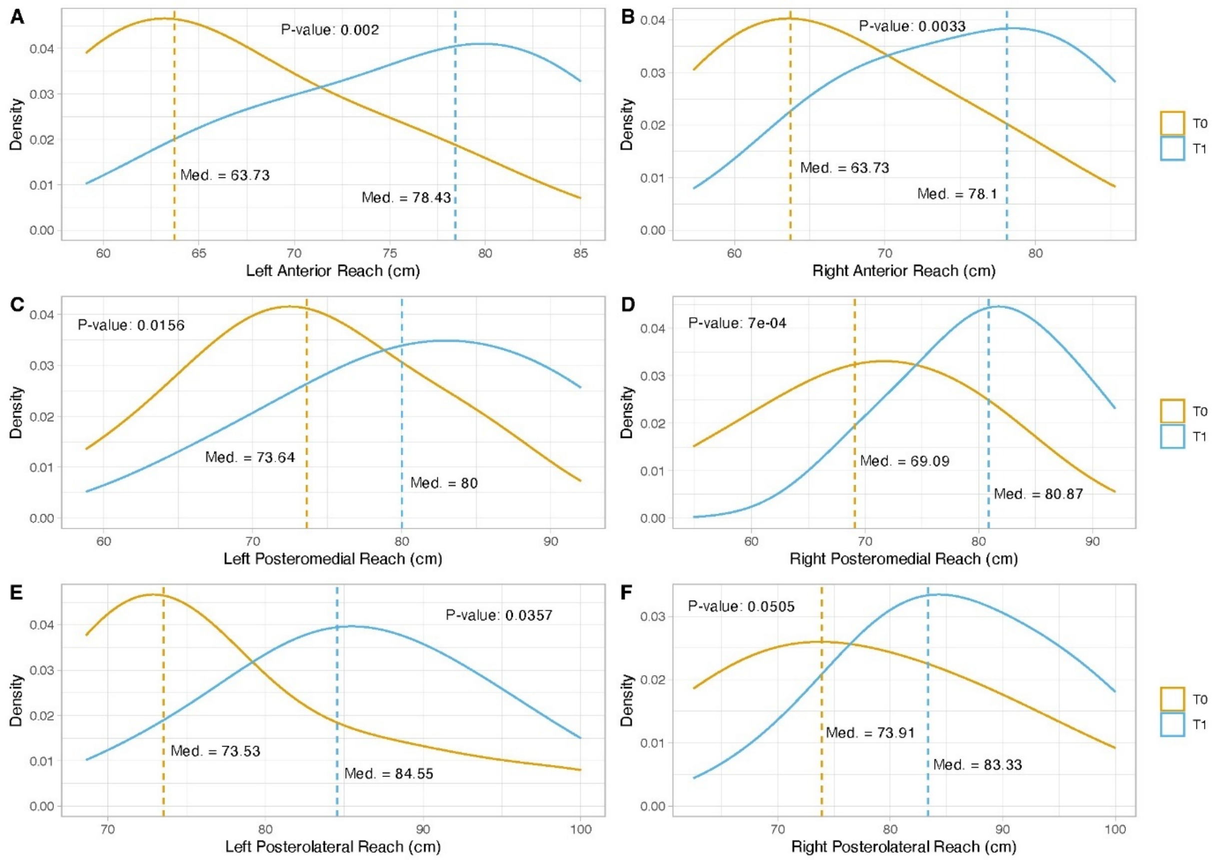

Figure 6. Comparison of medians in the reaches of the balance test between T0 and T1 in the FRG.

Med.: median; density: proportion of individuals.

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