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RESEARCH ARTICLE

# EFFECTS OF SIX WEEKS VIBRATION AND NON-VIBRATION FOAM ROLLING ON LOWER LIMBS' FITNESS COMPONENTS AMONG COLLEGIATE FOOTBALLERS

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**ABSTRACT**

Foam rolling is widely adopted in sports for post-exercise recovery through self-myofascial release. Recent advancements integrate vibration into traditional foam rollers, termed vibration foam rolling (VFR), which may enhance tissue stimulation, flexibility, and recovery. However, existing studies predominantly focus on acute VFR effects, with limited exploration of its prolonged impact on collegiate footballers. This study compared 6-week VFR and non-vibration foam rolling (NVFR) interventions on lower-limb fitness in male collegiate footballers (n = 30). Participants were randomized into VFR or NVFR groups, both completing twice-weekly standard football training followed by their assigned intervention. Fitness components—speed (20-m sprint), power (horizontal jump), agility (Illinois agility test), balance (Y-balance test), and flexibility (sit-and-reach)—were assessed pre-test, post-test 1 (after first session), and post-test 2 (post-6 weeks). Results indicated significant speed and power improvements in both groups, though VFR demonstrated superior acute-phase gains. Agility improved significantly only in the VFR group after both acute and 6-week interventions. Balance remained unchanged in both groups. Flexibility increased significantly in both groups after 6 weeks, but VFR yielded more pronounced short- and long-term improvements. Overall, VFR exhibited advantages in agility and flexibility enhancement, while both methods effectively improved speed and power. The findings suggest that VFR and NVFR are viable for enhancing lower-limb fitness in collegiate footballers, with VFR potentially offering additional benefits. Coaches and athletes may consider integrating foam rolling, particularly VFR, into training regimens to optimize recovery and performance. Future research should investigate long-term effects and sport-specific outcomes of foam rolling interventions.

# 1. Introduction

## 1.1 Study Background

Physical fitness components can be broadly divided into health-related and skill-related (Chu et al., 2016). Lower limbs' fitness components plays a key role in football competitions. Speed, explosive power, agility, balance, and flexibility of lower limbs' fitness components, which are particularly important for football players (Adil et al., 2018; Farley et al., 2020; Kariyawasam et al., 2019; Yusuf et al., 2022). Research by Rahnama et al. (2005) shows that better flexibility and joint mobility can help athletes make greater movements and complete more touches and passes, Manolopoulos et al. (2013) found that superior explosive power makes it easier for football players to maintain advantages when sprinting, jumping, shooting, etc. And Trecroci et al. (2018) pointed out that agile and flexible lower limbs can allow athletes to better control the ball and break through on the court. The combination of these lower limbs' fitness components and technical and tactical abilities will ultimately improve athletes' running distance, number of sprints, number of shots, etc. in the game, and may improve the team's ball possession rate, number of goals, winning rate (Carling, 2013; Sarmento et al., 2014), thus affecting the outcome of the entire game. The college period is a stage for collegiate footballer to effectively practice football skills and awareness. Collegiate footballers need to frequently perform high-intensity sprints, changes of direction, jumping and other actions during games, which also places extremely high demands on the fitness components of the lower limbs. However, during strenuous exercise in football matches, lower limbs' muscles will rapidly accumulate large amounts of lactic acid, leading to muscle fatigue and strength decline (Robineau et al., 2012; Rampinini et al., 2011). After football matches, this accumulation of fatigue not only affects the immediate performance of footballers, but may also have an adverse effect on subsequent training and competition. Therefore, it is particularly important to find effective recovery methods to reduce muscle fatigue and restore lower limb fitness components.

In recent years, foam rolling have been widely used in the sports field as a self-relaxation and massage tool (Wiewelhove et al., 2019). Using a foam rolling can produce effects similar to a massage, effectively promoting muscle recovery through mechanisms such as viscoelastic deformation caused by mechanical pressure, improved blood circulation, and regulation of nerve excitability. (Jo et al., 2018; Rey et al., 2019; Schroeder & Best, 2015). According to some research, foam rolling may increase muscle suppleness and joint range of motion (Alonso-Calvete et al., 2022). Furthermore, foam rolling has been shown in certain studies to enhance athletes' strength and performance in the near term, but the six-week benefits are unknown (Pagaduan et al., 2022). All things considered, foam rolling is a cheap and practical recuperation technique. Collegiate footballers may effectively relax their lower extremity muscles after workout by using foam rolling.

On the basis of traditional foam rolling, the emerging vibration foam rolling add vibration stimulation. Mechanical vibration can activate proprioceptors in tendons and cause stretch reflexes, thereby promoting muscle contraction and blood circulation (Nakamura et al., 2021). Vibration foam rolling may have greater physiological effects than regular foam rolling (Reiner et al., 2021). Current research shows that vibration foam rolling can significantly improve joint mobility and flexibility, but the effects on strength and performance are controversial (Jo et al., 2018; Rey et al., 2019). In addition, existing research mostly focuses on the general population or other sports, and research on footballers, especially collegiate footballers, is still very limited.

Collegiate footballers' high-intensity demands on lower limbs necessitate effective post-exercise recovery to prevent fitness decline and injury risks. Foam rolling interventions—particularly vibration-enhanced variants—show promise in improving flexibility and joint mobility through mechanical and neuromuscular stimulation, though their longitudinal effects on strength and performance remain unclear. This 6-week study investigates both vibration and non-vibration foam rolling's impacts on collegiate players' lower-limb fitness components, addressing current research gaps in sport-specific, non-acute application evidence.

The research question of this stuyd is *What are the effects of 6 weeks of vibration and non-vibration foam rolling on lower limbs' fitness components in collegiate footballers?*

The hypotheses of this study is*: Vibration foam rolling will lead to greater improvements in lower limbs' fitness components compared to non-vibration foam rolling in collegiate footballers following a 6-week intervention.*

This study examines six-week vibration (VFR) and non-vibration foam rolling (NVFR) interventions integrated with football training for collegiate athletes. Focusing on critical lower-limb attributes—speed, agility, power, balance, and flexibility—it addresses the prevalent muscle fatigue and injury risks in high-intensity sports. By evaluating both acute and sustained effects, the research provides practical insights for optimizing recovery protocols and injury prevention strategies. The empirical outcomes will guide coaches in evidence-based training program design while establishing foundational data for future sport-specific foam rolling research.

## 2. **Literature Review**

### 2.1 Acute Effects of Vibration and Non-Vibration Foam Rolling on Athletic Performance

Studies by Akcay et al. (2023), Tsai and Chen (2021), and Rey et al. (2019) found that vibration and non-vibration foam roller interventions did not result in acute improvements in speed, agility, flexibility, and jumping ability in volleyball players. Although most studies found that foam rollers were not able to significantly improve physical fitness components such as explosive power and agility in the short term, there are some different opinions. For example, a study by Lin et al. (2020) found that the use of vibration foam rollers after dynamic stretching significantly reduced muscle stiffness in badminton players, thereby helping to prevent sports injuries. This result may be due to the different requirements of different sports for lower limb fitness components. Explosive sports (such as volleyball and basketball) require higher explosive power and agility in the lower limbs, while sports such as badminton focus more on flexibility and coordination. Therefore, the acute effects of foam rollers on different lower limb fitness components are also different. In addition, the intervention time and test indicators of different studies may also lead to biased results. Existing research results show that the acute effects of foam rollers on exercise performance may vary depending on the characteristics of the exercise program, intervention time and test indicators. In explosive sports, it is difficult for foam rolling to significantly improve athletes' explosive power and agility in the short term; while in flexibility and coordination sports, vibration and non-vibration foam rollers may play a certain role in preventing injuries by reducing muscle stiffness.

There are relatively few studies on the non-acute effects of foam roller, but some findings suggest the potential of vibration and non-vibration foam rolling to improve fitness components. Pagaduan et al. (2022) compared the effects of 8 weeks of foam rolling, core stability training and a control group on lower limbs' muscle strength, jumping performance, dynamic balance and flexibility. The results showed that foam rolling can significantly improve core strength endurance and dynamic balance, but foam rolling has no significant impact on lower limbs' muscle strength, jumping performance and flexibility, This is consistent with previous research on the benefits of foam rolling in promoting performance of fitness components.

### 2.2 Effects of Vibration and Non-Vibration Foam Rolling on Post-Exercise Recovery

Multiple studies have supported the positive role of foam rolling in promoting post-exercise recovery, but there are some differences in the specific effects of different studies. Research by Rahimi and Amani-Shalamzari (2020) found that compared with passive recovery, futsal athletes' use of foam rolling after high-intensity competitions can improve lower limbs' strength, accelerate lactic acid clearance, and subjective recovery perceptions. The studies by Romero-Moraleda et al. (2019) and de Benito et al. (2019) further found that compared with non-vibration foam rolling, vibration foam rolling may have more advantages in relieving pain after sports muscle injuries and improving joint mobility, balance, and stability. This may be due to vibration stimulation enhancing muscle relaxation and blood circulation, thereby promoting injury recovery and body function recovery. However, the research of Nakamura et al. (2022) also pointed out that although the vibration foam roller can acutely increase the range of knee joint mobility, it will also lead to a short-term decrease in muscle strength, and the vibration frequency has no effect on this effect. Ruggieri et al. (2021) found that although hamstring activity increased in both legs using vibration and non-vibration foam rolling, foam roller, vibration foam roller, and vibration alone may decrease lower extremity performance measures, which may cause a decrease in athlete performance. Taken together, both studies suggest that while a vibration foam roller can improve joint range of motion and movement, it may decrease muscle strength and performance in the short term. Existing evidence generally supports the role of foam rolling in promoting post-exercise recovery. Vibration foam rolling may be more effective than non-vibration foam rolling in relieving muscle pain, improving joint mobility and balance ability through mechanisms such as enhancing muscle relaxation and blood circulation. However, vibration foam rolling may also cause muscle strength to decrease in the short term, so we need to weigh the pros and cons when using it.

### 2.3 Summary of Literature Findings

Current research on the non-acute effects of foam rolling on athletic performance and recovery remains limited and inconsistent. However, evidence suggests that vibration and non-vibration foam rolling may improve physical fitness, recovery, joint mobility, and reduce muscle stiffness and pain perception when integrated into training. While acute effects vary by sport—showing limited benefits in explosive sports like volleyball—foam rolling may aid injury prevention in agility sports like badminton. Future studies should prioritize large-scale non-acute research to systematically assess foam rolling's effects across athlete levels and further explore vibrating foam rolling's mechanisms. In summary, incorporating foam rolling into training may benefit athletes' fitness and recovery, though more research is needed to establish clear guidelines for diverse sports contexts.

## 3. Methodology and Procedures

### 3.1 Research Design

This study adopted a randomized controlled trial design, and aimed to explore the effects of 6 weeks of non-acute vibration and non-vibration foam roller intervention on the fitness components of the lower limbs of collegiate footballers. 30 male collegiate footballers participating in this experiment were randomly divided into a vibration foam rolling (VFR) group (n = 15) and a non-vibration foam rolling (NVFR) group (n = 15). The experiment lasted 6 weeks, where they performed a standard football training followed immediately by foam rolling intervention. Before the start of the experiment. The indicators of fitness components for the lower limbs that were selected for the study included: speed (20-m sprint test), horizontal power (horizontal jump), agility (Illinois agility test), balance (Y balance test), and flexibility (sit and reach test). These indicators came from the health and skills components, and were closely related to the specific demands of football (Adil et al., 2018; Farley et al., 2020; Kariyawasam et al., 2019; Yusuf et al., 2022). Data was collected at 3 points, namely pre-test (before the start of the experiment), post-test 1 (after first session of intervention) and post-test 2 (after six weeks of intervention) (Figure 3.1).

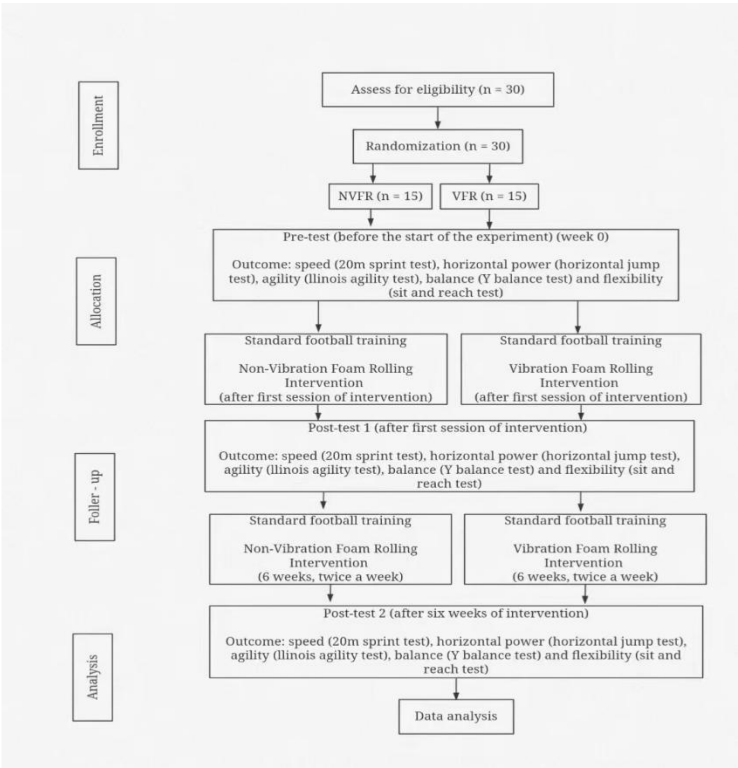


*Figure 3.1 The procedure of experiment.*

### 3.2 Participants

A priori power analysis was conducted using G * Power software (version 3.1.9.4) to determine the required sample size for this study; the test family was t test and the statistical test was means: difference between two independent means (two groups).

Based on the data from a similar study that measured effects of foam rolling on soccer-related components (Kaya et al., 2021), a lowest effect size of 0.8 was computed, in addition, an alpha level of 0.05, and a power of 0.65 were used for the calculation. The results showed that a total sample size of 28 participants (14 per group) would be sufficient to detect significant differences. Considering potential dropouts, 30 collegiate footballers were recruited as volunteers to participate in the study (Figure 3.2).

The inclusion criteria for this study were: (i) age 18-25 years old; (ii) at least 2 years of football training experience; (iii) no history of lower limb skeletal and muscle injuries in the past three months.

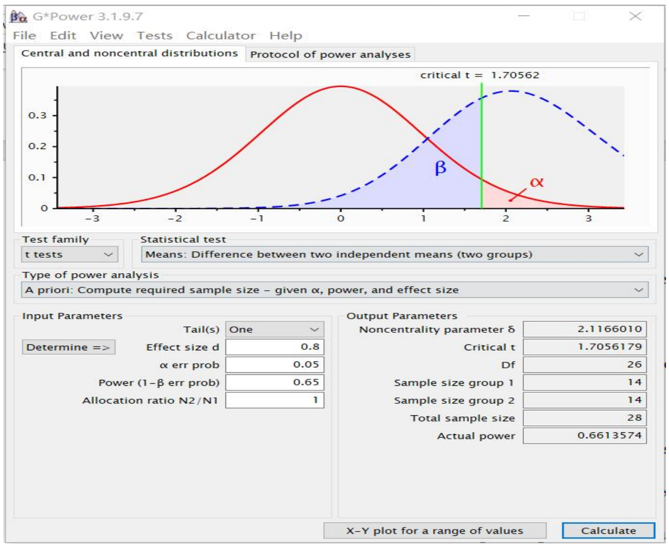


*Figure 3.2 G*Power analysis for sample size calculation.*

## 3.3 Materials & Equipment

This study used the following materials & equipment:

Cones, stopwatch, Y balance test tool, distance ruler, three light-trainer modules, Sit & Reach Box, several footballs, vibration and non-vibration foam rolling (PiRoller China, vibration frequency 45 Hz, 15cm*15cm*30cm, high-density EPP material).

## 3.4 Ethical Considerations

This study adheres to the ethical principles set out in the Declaration of Helsinki and relevant institutional guidelines. The University of Malaya Research Ethics Committee (UMREC) (Malaysia), approved this study. The reference number is UM.TNC2/UMREC_3693. All subjects signed an informed consent form before the experiment began and were informed of the purpose, methods, potential risks, and benefits of the study. Subjects were allowed to withdraw from the study at any time without giving any reason.

## 3.5 Fitness Component Test

### 3.5.1 Speed: 20-m sprint test

Subjects were positioned at the starting line behind cone A, prepared to sprint. A timekeeper was stationed at the finish line, using a stopwatch to time the sprints. Upon hearing the starting signal, subjects had to dash to the finish line as quickly as possible. Each participant was required to complete a minimum of three sprints, with a rest period of 2-3 minutes between each sprint. The best time of the three sprints was recorded

(Hernández-Davó et al., 2021) (Figure 3.3).

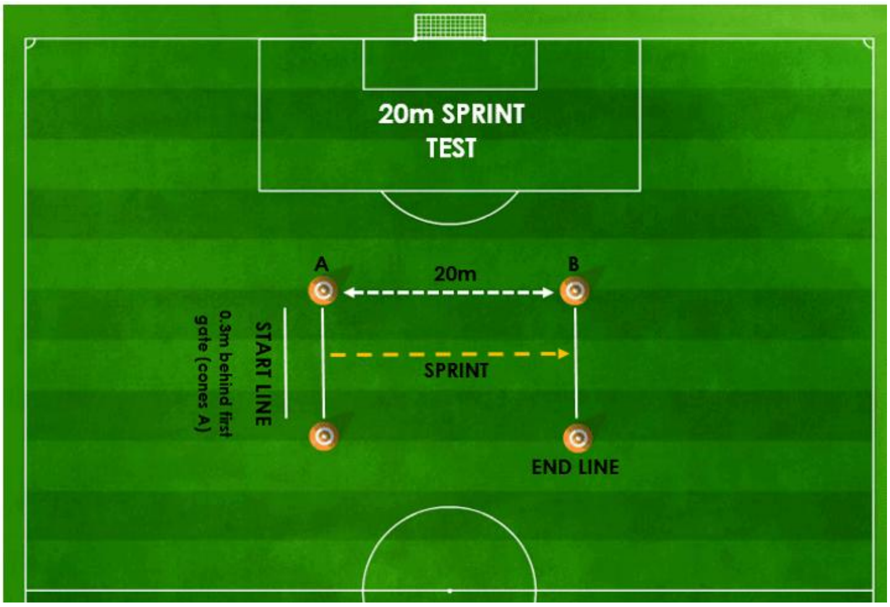


*Figure 3.3 Test configuration for the 20-m sprint test*

### 3.5.2 Power: horizontal jump test

A starting line was marked with tape on the ground. Subjects stood with their feet together, toes aligned with the starting line. To gain momentum, subjects were allowed to swing their arms backward before leaping forward horizontally, aiming to cover the maximum distance possible. The measurement was taken from the starting line to the nearest point of contact at the landing position. Subjects were given 2-3 attempts, with the longest valid jump recorded to the nearest centimeter. If any part of the subject's body touched the ground upon landing, the attempt was considered invalid (Mann et al., 2021) (Figure 3.4).

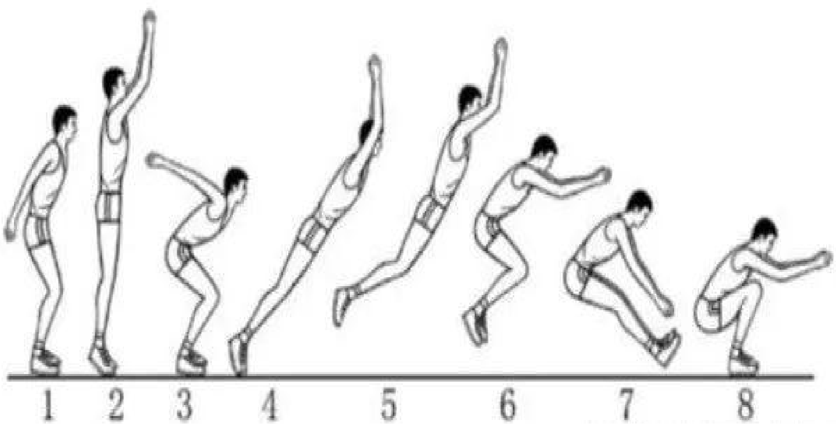


*Figure 3.4 Test configuration for the horizontal jump test.*

### 3.5.3 Agility: Illinois agility test

The track was 10 meters long and 5 meters wide, marked by four cones at the start, end, and two turning points. An additional four cones were evenly placed below the center, each spaced 3.3 meters apart. Subjects were instructed to start in a prone position, facing the starting line, with hands on their shoulders. Upon the "start" command, the stopwatch began, and the subject had to rise quickly, run around the track in the specified direction without knocking over any cones, and cross the finish line where the timer stopped. Each participant had only one attempt, with results recorded to an accuracy of 0.01 seconds (Amiri-Khorasani et al., 2010) (Figure 3.5).

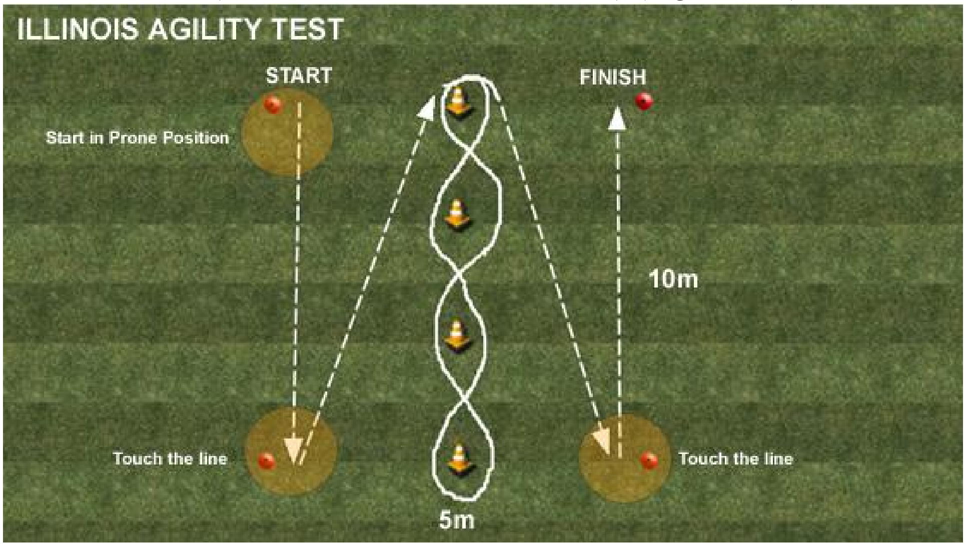


*Figure 3.5 Test configuration for the Illinois agility test.*

### 3.5.4 Balance: Y balance test

At the beginning of the Y balance test, the subject's lower limb length will be measured (distance from the anterior superior iliac spine to the midpoint of the medial malleolus of the ipsilateral foot), and then the subject will be instructed to stand at the central intersection of the Y-shaped configuration, placing one foot on the intersection, lifting the other foot off the ground, and placing both hands on their hips. In this single-leg stance, the subject will use the elevated foot to reach as far as possible in three directions: forward, posteromedial, and posterolateral. During each stretch, the toes must touch the test pad, but the supporting foot must remain stationary. The subject should make three attempts in each direction. Record the maximum stretch distance for each direction, sum these distances, divide by three times the length of the low limb, and multiply by 100 to calculate the overall score (Shaffer et al., 2013) (Figure 3.6).

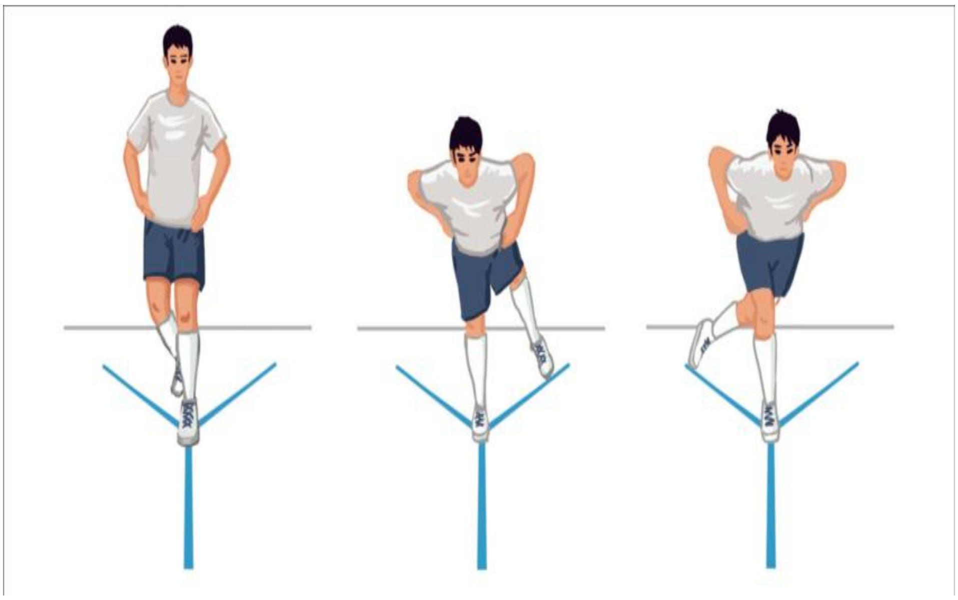

*Figure 3.6 Test configuration for the Y balance test.*

### 3.5.5 Flexibility: sit and reach test

The subject sat on a flat surface with their legs extended and feet flat against a vertical board, maintaining a distance of approximately 10-15 cm between the feet. The upper body was to be bent forward, and the arms extended straight ahead. Using the middle fingers of both hands, the subject pushed a cursor forward until it could no longer be moved. Two attempts were allowed, and the best result was recorded, with accuracy up to 0.1 cm (Su et al., 2017) (Figure 3.7).

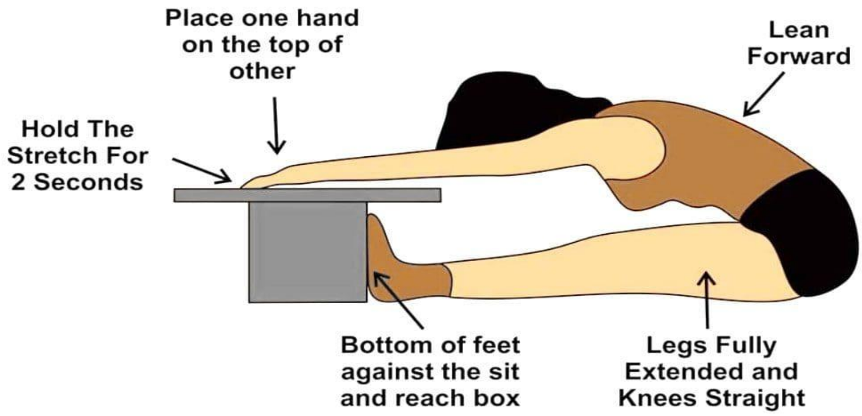


*Figure 3.7 Test configuration for the sit and reach test.*

### 3.6 Standard Football Training

All 30 participants participated in about 45 minutes of standard football training, including passing drills, shooting drills and sprinting drills. Standard football training lasted for 6 weeks, twice a week.

Passing drills: Two subjects stood 5-10 meters apart and passed the ball to each other using the inner part of the foot or the instep. The passes were ground balls. Each foot had to be used to pass the ball at least 50 times.

Shooting exercises: Subjects placed the ball on the penalty spot and shot at least 30 times, alternating between the left and right foot.

Sprinting drills: The tester set up five markers at 5-meter intervals. The subjects sprinted from the starting point to the first marker, then immediately turned and sprinted back to the start before proceeding to the next marker, increasing the distance with each turn. This sequence was 150 meters in total and subjects needed to complete it three times (Figure 3.8).

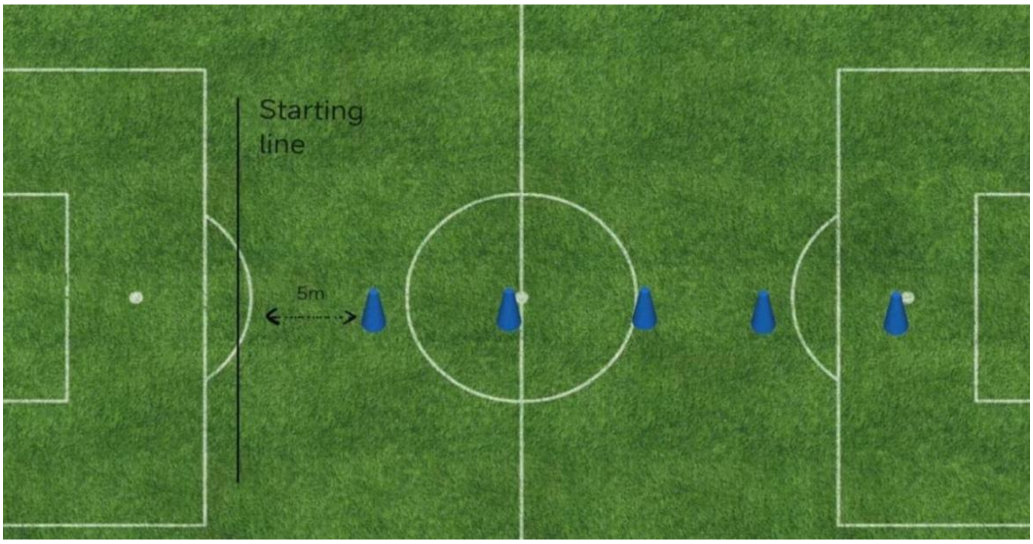


*Figure 3.8 Sprint practice venue.*

### 3.7 Vibration Foam Rolling Intervention

The intervention was based on a previous foam rolling study (Rey et al., 2017), in which the vibration foam roller group used vibration foam rollers to relax their lower limbs for 10 minutes after each standard football training.

The specific operation is as follows: The subject used their own gravity to roll back and forth on the vibration foam roller as smoothly as possible to relax the gastrocnemius, biceps femoris, quadriceps, and iliotibial band of the right and left legs. They performed 60 seconds of intervention on each area of the left and right legs (in the order of ABCD), and rested for 15 seconds after each intervention (Figure 3.9).

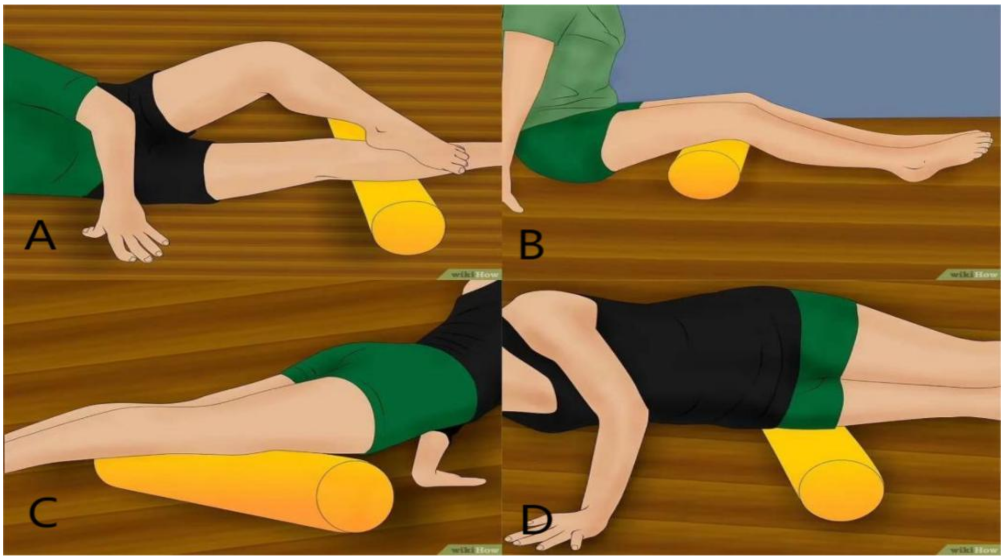


*Figure 3.9 Foam rolling technique illustration.*

### 3.8 Non-Vibration Foam Rolling Intervention

The non-vibration foam rolling group used the same intervention method as the vibration group for muscle relaxation. The only difference was using the same specs of non-vibration foam rolling from the same manufacturer.

### 3.9 Statistical Analysis

Descriptive statistics were calculated for all variables. All data was presented as mean

± standard deviation. The Shapiro-Wilk test was used to verify the normality of the data distribution. If the data followed a normal distribution, a 2-way analysis of variance (ANOVA) (3 time points * 2 groups) was used to analyze the effects of vibration and non-vibration foam rollers on each index of lower limbs' performance components across three tests (baseline test, first 1st post-test and 2nd post-test). If significant interactions were found, a Tukey post hoc multiple comparisons was used for pairwise comparisons. Data analysis was completed using SPSS version 25.0 software (SPSS Inc., Chicago, IL, USA).

## 4. Results and Discussion

### 4.1: RESULTS

#### 4.1.1 20-m Sprint

In the primary outcome analysis of the 20-meter sprint test, the ANOVA showed that there were a significant group effect (F(2, 28) = 40.86 P < 0.0001). However, the post-hoc analysis showed that there were significant drop in sprint time from pre-test to post-test 1 and from pre-test to post-test 2 in both VFR and NVFR. This results are shown in Figure 4.1.

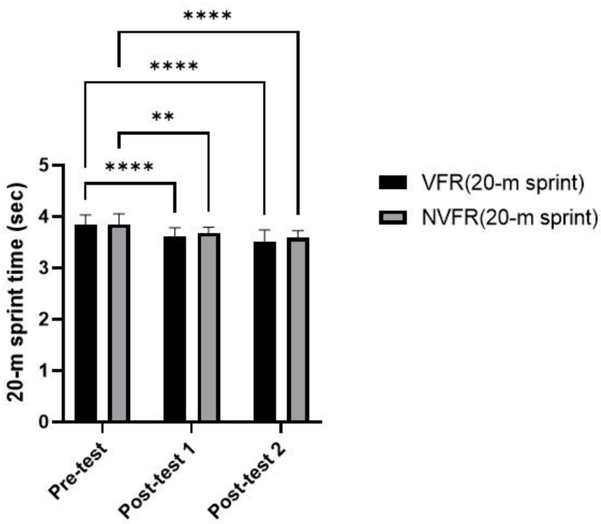


*Figure 4.1: 20-m sprint time results. **p < 0.01, ****p < 0.0001.*

#### 4.1.2 Horizontal Jump

The ANOVA of horizontal jump showed a significant time effect F(1.546, 21.65) = 46.52, P < 0.0001. The post hoc analysis indicated that there were significant increase in jump distance from pre-test to post-test 1, from pre-test to post-test 2, and from post-test 1 to post-test 2 in VFR. Meanwhile in the NVFR group, significant increase was found from pre-test to post-test 2 and post-test 1 to post-test 2. Unlike VFR, there is no increase from pre-test to post-test 1 in NVFR. This results are shown in Figure 4.2.

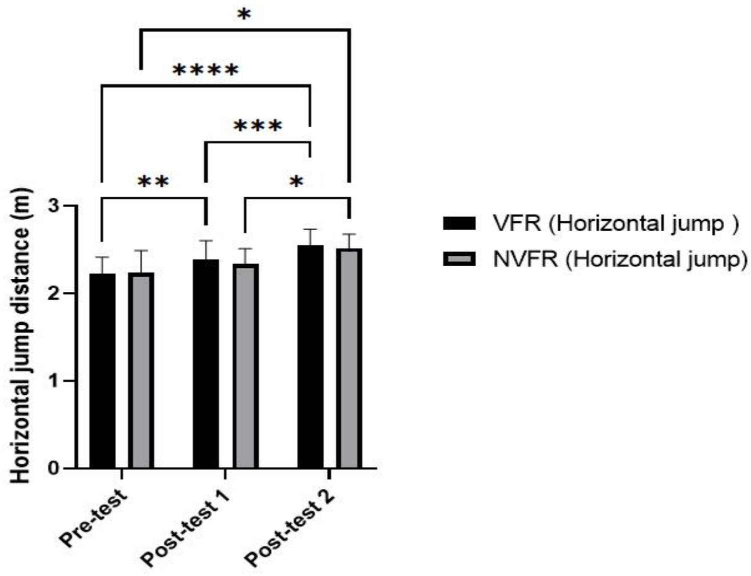


*Figure 4.2. Horizontal jump distance results.* *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ****$p < 0.0001$.

### 4.1.3 Illinois Agility Test

The ANOVA of Illinois agility test showed a significant time effect F (1.785, 24.99) = 18.35, P < 0.0001. The post hoc analysis indicated that there were significant increase in Illinois agility test score from pre-test to post-test 1, from pre-test to post-test 2 and from post-test 1 to post-test 2 in VFR. This results are shown in Figure 4.3.

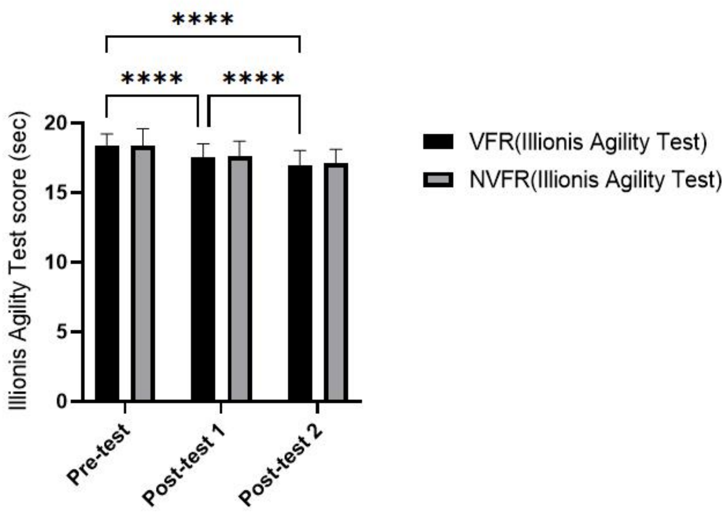


*Figure 4.3. Illinois agility test score results.* ****$p < 0.0001$.

### 4.1.4 Y Balance Test

The ANOVA showed significant time effect $F(1.904, 26.66) = 3.920$, $P = 0.0340$. However, post hoc test shows no differences between any group mean. The results are illustrated in Figure 4.4.

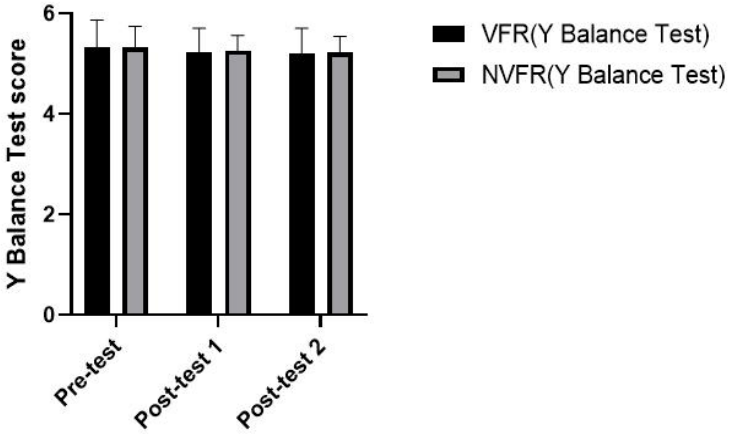


*Figure 4.4. Y balance test score results.*

### 4.1.5 Sit and Reach Test

The ANOVA of sit and reach distance showed a significant time effect $F(1.390, 19.46) = 49.47$, $P < 0.0001$. The post hoc analysis indicated that there were significant increase in sit and reach distance from pre-test to post-test 1, from pre-test to post-test 2 and from post-test 1 to post-test 2 in VFR. Unlike VFR, there is no increase from pre-test to post-test 1 and from post-test 1 to post-test 2 in NVFR. This results are shown in Figure 4.5.

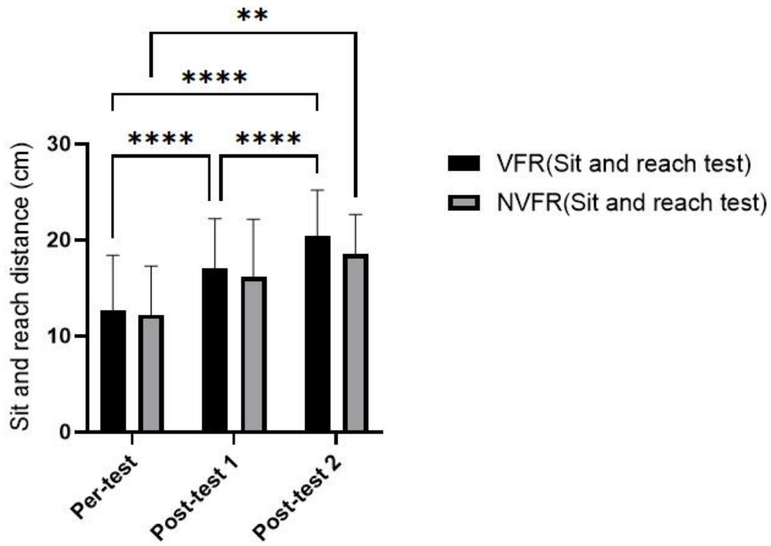


*Figure 4.5. Sit and reach distance results. **p < 0.01, ****p < 0.0001.*

## 4.2 Discussion

### 4.2.1 Introduction

A 6-week study examined vibration (VFR) and non-vibration foam rolling (NVFR) effects on collegiate footballers' fitness. Both groups significantly reduced 20-m sprint times across post-tests 1 and 2. In horizontal jump tests, VFR showed consistent improvements at all stages, while NVFR only achieved significant gains between post-tests. VFR also enhanced Illinois Agility Test performance progressively and demonstrated sustained flexibility improvements in sit-and-reach tests, whereas NVFR improved flexibility only in the final post-test. Y Balance Test results indicated temporal effects without intergroup differences. These findings suggest VFR may offer more consistent benefits across multiple performance metrics—particularly flexibility and explosive power—compared to NVFR's delayed effects in specific areas.

### 5.2.2 Effects of VFR and NVFR on Speed Among Collegiate Footballer

This study assessed acute and six-week vibration foam rolling (VFR) versus non-vibration foam rolling (NVFR) effects on collegiate footballers' sprint performance. Both groups showed 20-m sprint improvements across acute and six-week phases, aligning with Wiewelhove et al.'s (2019) meta-analysis findings. However, the greater acute-phase gains in VFR (vs. NVFR) may stem from vibration-enhanced neuromuscular activation (Romero-Moraleda et al., 2017). Notably, Rey et al. (2019) observed smaller effects in professionals, potentially due to collegiate athletes' higher sensitivity to interventions or this study's extended six-week duration—contrasting prior 24-hour protocols (Jey et al., 2019). Long-term improvements likely derive from sustained myofascial adaptation. Crucially, six-week outcomes showed no VFR-NVFR disparity, indicating comparable long-term efficacy despite VFR's acute advantages.

### 5.2.3 Effects of VFR and NVFR on Power Among Collegiate Footballer

This study found that after 6 weeks of intervention, both the VFR and NVFR groups showed significant improvements in horizontal jump performance, indicating improved lower limb explosive power. It is noteworthy, however, that the VFR intervention appeared to produce faster improvements, with significant improvements occurring after the first intervention period (Post-test 1), whereas the NVFR did not, even though both interventions ultimately resulted in significant improvements by the end of the study (Post-test 2). This is consistent with previous findings from acute NVFR, where Healey et al. (2014) found no acute effects of FR on jumping or low limb's strength performance compared with plank exercise. The reason for this may be that our research samples are relatively small. The study by Nakamura et al. (2021) also concluded that the acute effect of jumping with NVFR was not significant. Our research samples are less than 20. Future studies can increase the sample size to explore the potential acute effects of NVFR on horizontal jumping. Although there is currently a lack of evidence for the positive effects of six-week VFR on horizontal jumping, I believe that six-week use of VFR may improve jumping ability through multiple mechanisms, including increased muscle activation, reduced neural inhibition, and improved muscle flexibility to improve jump performance (Romero-Moraleda et al., 2019). It is worth noting that although the improvement in the VFR group was slightly greater than that in the NVFR group, the difference was not significant. This may indicate that the vibration function may not be a decisive factor for six-week intervention.

### 5.2.4 Effects of VFR and NVFR on Agility Among Collegiate Footballer

This study found that only the VFR group showed significant improvements in both the acute and chronic phases of the Illinois Agility Test, and the six-week effect was better. This is consistent with some previous studies. Tsai and Chen (2021) found that a single foam roller intervention had no significant effect on the agility of volleyball players. Chen et al. (2021) found that acute use of VFR can effectively improve the agility of taekwondo athletes. This may be because both sports require athletes to have a high level of agility. Football players need to change direction quickly to avoid opponents, while taekwondo athletes need to move quickly to attack and defend. However, in contrast, Lin et al. (2020)'s study found that dynamic stretching has a better acute effect on badminton players' agility than dynamic stretching followed by a vibration foam roller. Acute use of VFR does not necessarily significantly improve agility. The possible reason is that this study used a 45 Hz VFR, while Lin et al. (2020) used a 28 Hz VFR, which may be related to the vibration frequency, Luo et al. (2005) suggested that vibration stimulation at 30 to 50 Hz may be most effective for muscle activation.

Interestingly, while this study did not find any significant changes in NVFR, the results of Peacock et al. (2014) found that acute use of foam rollers can improve athletes' agility performance. This may be because Tsai and Chen (2021) only studied the acute effects of foam roller intervention, while Peacock et al. (2014) also studied acute effects but combined dynamic warm-up. This combination may enhance the effect of the foam rolling intervention and provide athletes with a more comprehensive warm-up. Dynamic warm-up can improve athletes' athletic performance on its own, and combined with foam rolling, it may significantly improve athletes' agility performance due to a synergistic effect.

However, it is worth noting that the difference between the VFR group and the NVFR group did not reach statistical significance. This suggests that although the NVFR group did not show significant improvement in agility, non-vibration foam rollers are also effective in improving agility, and vibration foam rollings may be more effective. This finding provides new directions for future research and encourages future scholars to further explore the potential benefits of non-vibration foam rollers (NVFR) in improving agility. This also provides options for coaches and athletes, especially when considering cost-effectiveness.

### 5.2.4 Effects of VFR and NVFR on Balance Among Collegiate Footballer

The performance on the Y balance test did not change significantly in the VFR and NVFR groups, which is consistent with existing studies. Junker and Stöggl (2019) found that 8 weeks of foam rolling had no significant effect on balance and muscle performance. However, Peacock et al. (2014) showed that foam rolling may have potential benefits on proprioception and neuromuscular control. This discrepancy may be due to several factors. First, the Y balance test may not reflect the improvement after the foam rolling intervention because the test mainly assesses dynamic balance. Balance is a complex skill that involves the integration of multiple sensory systems and motor responses (Hrysomallis, 2011). Our 6-week intervention period may not be sufficient to induce significant changes in these abilities due to the time required for physiological adaptations to occur. In addition, our subjects were college football players, and football training itself involves a lot of balance and coordination exercises (Zago et al., 2015), so they may have already had high balance abilities, and additional foam rolling is unlikely to produce significant improvements. At the same time, some earlier studies used athletes from the general population or other sports, who may have more room for improvement. Finally, the Y balance test may not be sensitive enough to detect small improvements in the short term. According to Brown et al. (2020), force plate testing can better capture subtle changes in balance control. This suggests that we may need to combine multiple measurement tools when evaluating short-term effects. In conclusion, the use of more comprehensive balance tests, such as static balance, dynamic balance, and functional balance tests, in future studies may help to fully understand how foam rolling affects balance (Konrad et al., 2022).

Although there were no statistically significant differences, we observed that some participants showed slight improvements after the intervention, which suggests that the effect of foam rolling on balance ability is individualized and may be affected by factors such as initial balance level and physical fitness.

### 5.2.5 Effects of VFR and NVFR on Flexibility Among Collegiate Footballer

This study found that both the VFR and NVFR groups showed significant improvements in the sit-and-reach test after the six-week intervention, with the VFR group showing greater improvements. This is consistent with the results of a systematic review by Beardsley and Skarabot (2015), who found that foam rolling interventions were effective in improving lower limb flexibility and range of motion. However, our results differ from previous studies in some respects. For example, Pagaduan et al. (2022) found that 8 weeks of foam rolling had no significant effect on flexibility. This may be because we used the sit-and-reach test, which primarily assesses flexibility in the lower back and hamstrings, whereas some previous studies may have used different flexibility testing methods and assessed different muscle groups (Cheatham et al., 2015; Pagaduan et al., 2022).

However, the NVFR group did not show significant within-group changes in the short term, which is different from existing research that found that flexibility in elite collegiate footballers improved rapidly after a foam rolling intervention (Aune et al., 2018). This may be because participants expected lower values for NVFR than VFR, which may affect their perception and performance (Lim et al., 2019).

In addition, we observed more significant improvements in the VFR group. This may be because vibration stimulation enhances the activity of mechanoreceptors, thereby promoting muscle relaxation and blood circulation (Reiner et al., 2021). Vibration can also further improve flexibility through neurophysiological mechanisms, such as regulating pain perception and increasing stretch tolerance (Aboodarda et al., 2015).

While enhancing flexibility benefits footballers, excessive gains without corresponding stability training may increase joint injury risks (Behm et al., 2016). Our findings demonstrate vibration foam rolling (VFR) accelerates short-term flexibility improvements, whereas non-vibration foam rolling (NVFR) requires extended six-week interventions to achieve comparable effects. Practical applications suggest prioritizing VFR for acute-phase recovery needs while considering NVFR as a cost-effective long-term option, particularly when combined with stability training to mitigate potential risks. Future research should employ extended intervention timelines and precision measurement tools to better quantify NVFR's cumulative effects, with additional exploration of synergistic protocols integrating foam rolling with complementary training modalities.

### 5.2.6 Limitation

This study had several limitations: (1) Textural differences between vibration/non-vibration foam rollers may have influenced outcomes—future studies should standardize equipment; (2) Uncontrolled variables like rolling speed/pressure across participants require measurement and standardization; (3) Missing test familiarization sessions potentially affected initial measurements; (4) Absence of a control group prevents conclusive attribution of results to interventions alone. Addressing these through controlled designs and standardized protocols would enhance validity.

## 5. Conclusion and Suggestion

This study demonstrates vibration (VFR) and non-vibration foam rolling (NVFR) benefits for collegiate footballers' lower limb fitness. Both interventions improved speed, agility, power, and flexibility, with VFR showing marginally better gains—particularly in sustained flexibility and explosive power—though statistical differences between methods were inconsistent. While balance showed no improvement, this warrants further investigation. Practically, coaches should incorporate either foam rolling type into training regimens based on equipment availability and preference, as both enhance performance and may reduce injury risks. Future research should explore long-term effects and sport-specific applications.

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