Submitted: 07 March, 2024 Accepted: 02 April, 2024 Published: 30 July, 2024 DOI:10.22514/jomh.2024.114

JOMH
Journal of Men's Health

ORIGINAL RESEARCH

Effects of foam rolling and static stretching training in youth soccer players with hip joint range of motion restriction

Gaofei Zhang[1], Yonghwan Kim[2,*], Moonyoung Choi[3,*]

[1]Physical Education College, Zhoukou Normal University, 466000 Zhoukou, Henan, China
[2]Department of Physical Education, Gangneung-Wonju National University, 25457 Gangneung, Republic of Korea
[3]Department of Sports Science Convergence, Dongguk University, 04620 Seoul, Republic of Korea

***Correspondence**
yhkim@gwnu.ac.kr
(Yonghwan Kim);
dory0301@dongguk.edu
(Moonyoung Choi)

Abstract

Hip range of motion (ROM) restriction is commonly observed in youth soccer players. This study aimed to investigate the effects of foam rolling training (FRT) and static stretching training (SST) on youth soccer players who have restricted hip ROM. The study included 34 youth soccer players with hip ROM restrictions, who were divided into two groups: FRT (n = 17, 15.9 ± 1.3 years) and SST (n = 17, 15.9 ± 1.7 years). Both groups were diagnosed with hip ROM restriction and enrolled in the study, then performed foam rolling and static stretching programs three times a week for six weeks. The Copenhagen Hip and Groin Outcome Score (HAGOS), and hip ROM, Lower Quarter Y-Balance Test (YBT-LQ), and isokinetic hip strength test were measured before and after intervention. The results showed that both FRT and SST were effective in improving hip function, as measured by HAGOS, and in increasing hip ROM, particularly flexion, abduction and internal rotation ($p < 0.05$). External rotation was significantly increased only in the SST group ($p < 0.05$). Both FRT and SST also improved YBT-LQ ($p < 0.05$). However, the SST group showed higher reach distances than the FRT group in all directions after training ($p < 0.05$). Both groups improved isokinetic hip strength in flexion and abduction movements, but when compared between groups, the FRT group showed greater improvement in peak torque ($p < 0.05$). In conclusion, FRT was more effective in reducing symptoms and pain and improving muscle strength, while SST improved hip mobility and dynamic balance more broadly. These results suggest that including both foam rolling and static stretching in a training program to optimize hip ROM and function in youth soccer players may be effective.

Keywords

Football; Mobility; Restriction; Foam rolling; Static stretching; Dynamic balance; Strength; Adolescents

1. Introduction

Soccer is a sport that requires quick direction changes, sprints, and powerful lower-body movements. The hip joint plays a vital role in performing these core soccer techniques. It is a crucial link in the kinetic chain, transferring force from the lower extremities to the upper body and *vice versa*. In soccer, this dynamic transfer of force is essential for activities such as kicking the ball powerfully or changing direction quickly [1].

Performing soccer skills requires multidirectional movement, which demands a wide range of motion (ROM) of the hip joint [2]. Movements such as cutting, pivoting, and quick lateral movements rely heavily on the hip joint's ability to move fluidly [3]. However, these activities involve repetitive, strong use of certain muscle groups, especially the hip extensors and internal rotators. This can create an imbalance with their antagonist muscles, resulting in restricted hip ROM for flexion and external rotation [4] (Fig. 1). Restricted hip ROM can directly affect a player's performance by altering the kinetics of the lower extremities. It can limit the power and accuracy of kicking and decrease the overall effectiveness of agility and speed in maneuvers [5]. This is particularly true for youth soccer players during a rapid growth period. They often report decreased natural tightness and flexibility around the hip joints because their bones grow faster than the flexibility of their muscles and tendons [6].

However, the increased risk of injury associated with a restricted hip ROM is more concerning than the immediate impact on performance [7]. Athletes with limited hip mobility are reported to be vulnerable to various musculoskeletal injuries. Tak *et al*. [8] confirmed through a systematic review that reduced total hip ROM was the most consistently associated risk factor for groin pain in athletes. Hogg *et al*. [9] compared soccer players with non-contact anterior cruciate ligament injuries to a control group and reported that decreased hip ROM, especially internal rotation, was strongly associated

FIGURE 1. Restricted hip range of motion example.

with anterior cruciate ligament injuries.

Additionally, restricted hip ROM during adolescence can cause musculoskeletal imbalance and lead to inappropriate mechanical movement patterns, which can affect an athlete's performance decline [10, 11]. These injuries require active management because unresolved problems can present a potential risk factor. Moreover, systematic and organized management can prevent the development of serious conditions such as osteoarthritis or chronic pain syndrome in the future and can greatly contribute to the athlete's career and quality of life [8]. Foam rolling training (FRT) and static stretching training (SST) are two promising non-invasive intervention strategies known for improving flexibility and joint mobility [12, 13]. SST is a traditional technique that is well-known to reduce muscle stiffness by improving the elasticity and extensibility of soft tissues [14]. Furthermore, several studies have shown that foam rolling, a self-release technique, is an effective strategy for relieving tension in muscles and fibrous tissues [15, 16].

However, there is a lack of research specifically targeting effective interventions to improve hip ROM in youth soccer players, and these interventions are limited when applied to them. A comparison of effective interventions to improve hip ROM has not yet been investigated. In this study, we used FRT and SST interventions on youth soccer players with limited hip mobility and compared changes in subjective hip score, hip ROM, dynamic balance, and isokinetic hip strength.

2. Materials and methods

2.1 Participants

Forty-four high school male soccer players were included in a study after being diagnosed with hip ROM restriction through clinical evaluation by an orthopedic surgeon. However, ten of the volunteers were excluded because they did not consent after hearing the explanation, had recently worsened pain, or had other health problems. The remaining 34 male high school soccer players were included in the intervention training group. Exclusion criteria for the study were general surgery on neurological or musculoskeletal structures, other hip pathologies, chronic musculoskeletal treatment, and severe acute lower extremity or head injury prior to recruitment. The selected players were divided into two groups, with 17 assigned to FRT for even numbers and 17 assigned to SST for odd numbers. Before and after the intervention, the players completed questionnaires and functional tests and were trained three times a week for six weeks. The patient (or their parent or legal guardian in the case of children under 16) gave their written consent for examination and publication for the purpose of the study.

2.2 Subjective hip function

The Copenhagen Hip and Groin Outcome Score (HAGOS) was used as a self-assessment method in the study. The reliability and validity of HAGOS are well supported, evidenced by high test-retest reliability with intraclass correlation coefficients ranging from 0.82 to 0.91, and statistically significant correlation coefficients for convergent construct validity (0.37–0.73) and responsiveness (0.56–0.69) [17]. It involved entering subjective hip joint status through a questionnaire [18], which had a total of 37 questions and consisted of six sub-scales: pain (10 items), symptoms (7 items), physical function in daily living (5 items), physical function in sport and recreation (8 items), participation in physical activities (2 items), hip and/or groin related quality of life (5 items). Each question was scored on a 5-point Likert scale from 0 to 4. Each sub-scale was converted to a score out of 100, and the overall score was the average score of the six sub-scales. A score of 100 indicated a healthy state and a lower score indicated a poorer subjective state.

2.3 Hip range of motion

The hip ROM of athletes was measured using a universal goniometer (Baseline® Model 12-1000, Fabrication Enterprises Inc., White Plains, NY, USA) [19], with extension performed in the prone position and flexion performed in the supine position. The stationary arm was positioned at the lateral midline of the pelvis, and the movement arm was positioned at the lateral midline of the femur when using the goniometer. The reference point was set at the greater trochanter. Adduction and abduction were measured in the supine position, with the goniometer centered on the anterior superior iliac spine (ASIS). Internal and external rotation were measured while sitting, with the knee flexed 90°. The anterior aspect of the patella was used as a reference point, with the stationary arm perpendicular to the floor and the movement arm at the tibia's anterior midline. All measurements were taken as the athlete's maximum active ROM, and angle measurements were repeated twice, with higher values recorded. If the error exceeded 3°, a re-measurement was conducted.

2.4 Dynamic balance

YBT-LQ is a test that evaluates dynamic balance, including flexibility, strength, stability and proprioception of the lower extremities. YBT equipment (Y Balance Test™, Cedar Park, TX, USA) was used for the test [20]. An experienced examiner (physical therapist with more than 5 years of clinical experience) demonstrated the correct testing posture and movement sequence and then provided participants with an opportunity to practice. Participants then took a single leg stance with one foot on the stance plate in the center of the YBT equipment for testing. To take measurements, stretch the other leg as far as possible while maintaining balance, and push the reach indicator out in the anterior (ANT), posteromedial (PM), and posterolateral (PL) directions with the tip of the toe. When the extending leg touched the ground or the standing leg's heel came off the stance plate, the measurement was retaken. Participants performed a series of movements in a total of three directions twice, and the higher record was analyzed.

2.5 Isokinetic hip strength

To measure the players' isokinetic hip strength, an isokinetic dynamometer (Humac Norm, CSMi, Stoughton, MA, USA) was used to evaluate the flexion, extension, adduction and abduction strengths of the hip joint [2, 21]. Participants lay on an examination chair, and the rotation axis of the dynamometer was precisely aligned with the anatomical axis of the hip joint. The axis of rotation for flexion and extension was set based on the greater trochanter of the femur in the supine position, and the axis of rotation for adduction and abduction was adjusted based on the ASIS in the side-lying position. To reduce compensatory movements during the test, straps were used to secure the pelvis and torso, and the dynamometer's hip attachment was placed on the distal thigh above the knee.

The evaluation involved concentric contraction at an angular velocity of 30°/s. Before the test, an experienced examiner explained the procedures and methods thoroughly, and participants were given several opportunities for prior practice. The hip joint's ROM for testing was set to 0 to 100° for flexion and extension and 0 to 45° for adduction and abduction in a neutral position. Participants took the main test four times, following two practice sessions. To reduce the impact of the lower extremity segment's weight on the results, the lever arm was moved close to the horizontal position, and gravity correction was applied. The peak torque value, measured in newton meters (Nm), was converted to peak torque per kilogram (kg) of body weight and normalized to the relative muscle strength value (unit: Nm/kg).

2.6 Training program

2.6.1 Static stretching training

The SST program involved active static stretching and was conducted for six weeks. Participants in the SST group underwent a training program for 40 minutes per session, three times a week. The program session consisted of a 10-minute warm-up, 20 minutes of active static stretching, and a 10-minute of cool-down. To increase whole body temperature and promote blood circulation, participants performed warm-up and cool-down activities by running on a treadmill for 10 minutes each at an intensity equivalent to 40–60% of their maximum heart rate (HRmax), as calculated by standard formulas (HRmax = 220 − age) [22]. The heart rate of participants on the treadmill was monitored in real-time using an electronic heart rate monitoring device (Polar H10, Polar Electro, Bethpage, NY, USA). The target muscle groups for improving hip ROM were set to be the same muscles as the FRT group. Participants were advised to perform active static stretching for each target muscle group in a controlled manner, avoiding bouncing movements. According to the most recent guidelines updated by the American College of Sports Medicine (ACSM), maintaining static stretches for 10 to 30 s is effective for most individuals in improving flexibility, with a recommended total of 90 s per joint [22]. Following these guidelines, the participants repeated a cycle of 30 s of static stretching and 30 s of rest for each targeted muscle group, doing this cycle three times. To effectively stretch the target muscle, participants were advised to perform stretching at an intensity corresponding to a visual analog scale (VAS) score of 7 to 8 for pain at the end range of ROM [15]. The active static stretching posture for each target muscle group is illustrated in Fig. 2.

2.6.2 Foam rolling training

The FRT program used a foam roller (Hyperice, Vyper 2.0, Irvine, CA, USA) made of ethylene vinyl acetate with a diameter of 15 cm and a length of 90 cm. Participants in the FRT group trained three times a week for six weeks, with each session lasting a total of 40 minutes. The program consisted of a warm-up, foam rolling, and a cool-down. The warm-up and cool-down activities involved treadmill running, employing the same method as used by the SST group. During the foam rolling portion of the program, participants foam rolled for 20 minutes, spending 3 minutes on each target muscle group on the symptomatic limb. The target muscle groups were the Hip Flexors, Gluteal muscles, Adductors, Tensor Fasciae Latae (TFL), Rectus femoris, and Hamstrings [23]. Each target muscle group was foam rolled for a cycle of 60 s, followed by 30 s of rest, repeated twice. Participants were trained on the visual analogue scale (VAS) ranging from 0 to 10 and advised to perform foam rolling at an intensity corresponding to a pain level of 7 to 8 on the VAS for effective stimulation (Fig. 3) [15].

2.7 Data analysis

The data were analyzed parametrically after testing for normality using the Shapiro-Wilk test. The sample size of participants was calculated using G*power software (version 3.1.9.4, Uni-

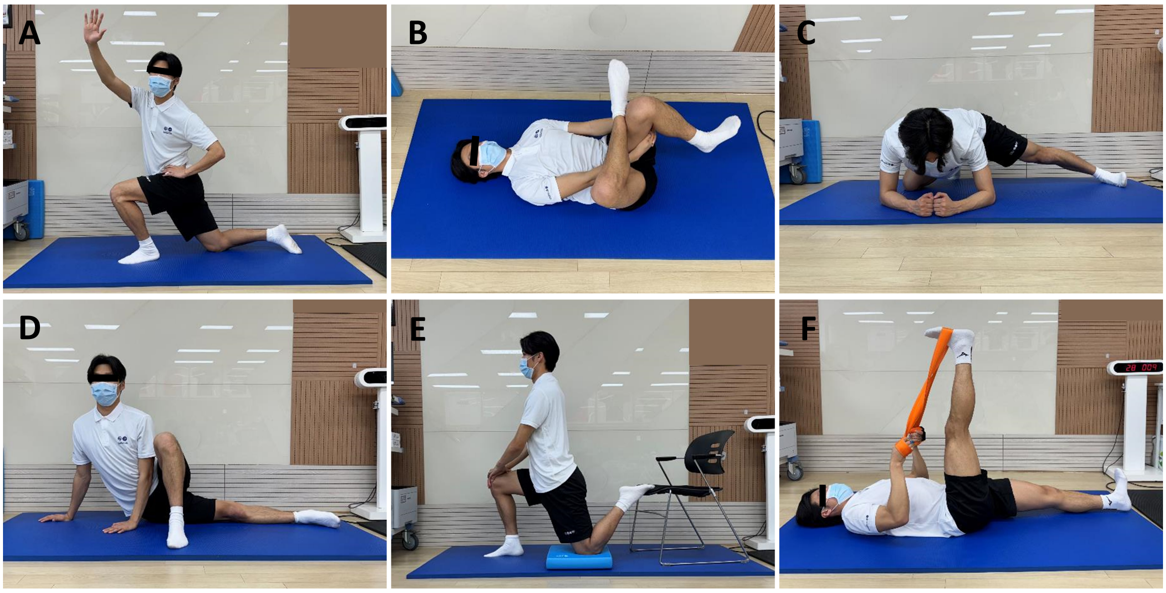

FIGURE 2. Static stretching training. (A) Hip Flexors; (B) Gluteal muscles; (C) Adductors; (D) Tensor fasciae latae; (E) Rectus femoris; (F) Hamstrings.

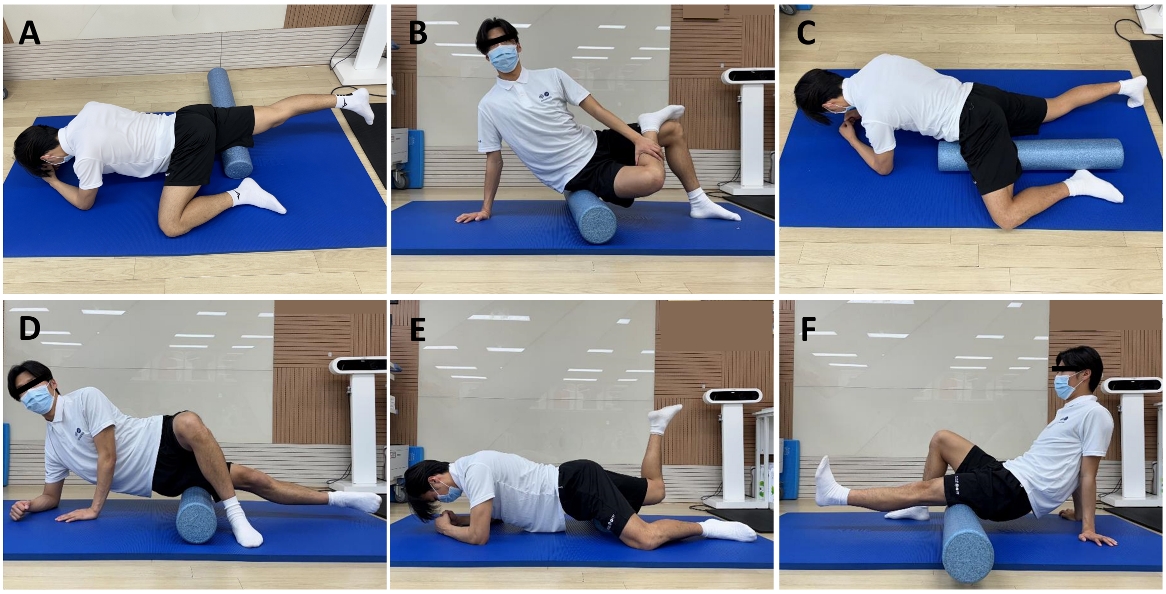

FIGURE 3. Foam rolling training. (A) Hip Flexors; (B) Gluteal muscles; (C) Adductors; (D) Tensor fasciae latae; (E) Rectus femoris; (F) Hamstrings.

versity of Düsseldorf, Düsseldorf, North Rhine-Westphalia, Germany) with F-test and repeated measurers, with-between interaction (Effect size (medium) $f = 0.25$, α err prob = 0.05, and power = 0.80) as the calculation conditions. The outcome was a critical F of 4.14, a denominator df 32.0, and a total sample size of 34. To compare demographic characteristics and baseline kinematic and kinematic variables between groups, independent sample t-tests were conducted. A paired t-test was used to compare before and after intervention by training group, and a repeated two-way analysis of variance (ANOVA) was performed to test the interaction between groups and time. Statistical significance (p) was determined by setting the 0.05 level. The data were analyzed using SPSS (version 25.0; IBM Corp, Armonk, NY, USA).

3. Results

3.1 General characteristics of participants

The participants were divided into groups, and their general characteristics are presented in Table 1. The groups did not differ significantly in terms of age, height, weight, body mass index, player experience, position, restricted ROM side and dominant side.

3.2 Subjective hip function

Table 2 provides a comparison of the HAGOS scores between the groups, which were measured to evaluate subjective hip function. The scores related to symptoms, pain, activities of daily living, sport and recreation, physical activity, and quality

TABLE 1. General characteristics of participants.

Variables	SST (n = 17)	FRT (n = 17)	t or χ^2	p-value
Age (yr)	15.9 ± 1.3	15.9 ± 1.7	0.180	0.858
Height (cm)	173.4 ± 3.9	173.5 ± 6.9	−0.024	0.981
Weight (kg)	69.3 ± 8.7	70.0 ± 9.8	−0.264	0.793
Player career (yr)	8.9 ± 1.5	9.5 ± 2.1	−1.330	0.193
Restricted ROM side, Left/Right (n)	8/9	10/7	0.472	0.492
Dominant side, Left/Right (n)	5/12	6/11	0.134	0.714
Position, DF/MF/FW (n)	5/10/2	6/8/3	0.513	0.774

Data are expressed as mean ± standard deviation or number; SST, static stretching training; FRT, foam rolling training; ROM, range of motion; DF, defender; MF, midfielder; FW, forward.

of life were significantly increased after training compared to before training, for both the FRT and SST groups. When comparing the two groups, the FRT group showed a significantly greater improvement in the sub-scales related to symptoms and pain, and the interaction effect of time and group was significant.

3.3 Hip range of motion

Table 3 displays the training effect on hip ROM. After training, both the FRT and SST groups showed a significant increase in hip flexion, abduction, and internal rotation ROM, while external rotation significantly increased only in the SST group. However, there were no significant changes in extension and adduction for both groups. In a comparison between both groups, the SST group showed significantly greater ROM in all motions than the FRT group after training. Moreover, interactions by time and group were found in flexion, abduction, internal, and external rotation.

3.4 Dynamic balance

Table 4 shows the differences between groups in YBT-LQ, which was measured to evaluate dynamic balance. After training, both the FRT and SST groups showed a significant improvement in the anterior, posteromedial, and posterolateral reach distances of the involved limb compared to before training. In comparison between both groups, the SST group showed significantly higher reach distances in all directions after training than the FRT group.

3.5 Isokinetic hip strength

Table 5 displays the between-group differences in isokinetic hip strength. Both FRT and SST groups showed a significant improvement in peak torque (Nm) in flexion and abduction after training, but there were no significant changes in extension and adduction. In a comparison between both groups, the FRT group showed a more significant improvement in flexion and abduction than the SST group after training, and there was also an interaction effect.

4. Discussion

The purpose of this study was to examine the impact of FRT and SST on youth soccer players who have restricted hip mobility. The study focused on how these training interventions affect subjective hip function, ROM, dynamic balance and strength of the players. By gaining insight into how FRT and SST contribute to these aspects, the goal was to optimize training protocols to reduce pain and symptoms and improve performance in youth soccer players with restricted hip mobility. The findings reveal that both FRT and SST interventions, conducted over six weeks, significantly improved overall variables of subjective hip function and dynamic balance, as well as certain variables of ROM and isokinetic strength, in youth soccer players with restricted hip ROM.

The study found that one of the main outcomes was improvement in ROM. In particular, ROM is a crucial aspect of the study because it is the decisive basis for the diagnosis of a restricted hip. In a previous study, AlTaweel *et al*. [2] targeted professional soccer players and found a significant difference in hip ROM between players based on their field position. This means that the hip ROM is linked to physical and technical factors specific to soccer players' specific tactics and responsibilities for each position. The differences in hip ROM outcomes observed in the FRT and SST groups in our study necessitate a specific interpretation based on biomechanical and physiological mechanisms. This interpretation investigates how each intervention modality influences hip ROM *via* distinct but complementary pathways. Junker *et al*. [24] previously studied the effects of foam roll myofascial release versus contract-relax proprioceptive neuromuscular facilitation stretching in 40 healthy men. A 4-week randomized controlled trial found that foam rolling and proprioceptive neuromuscular facilitation (PNF) stretching had similar effects on improving flexibility. During static stretching, mechanical stress and the total time under tension contribute to morphological adaptation [25]. In a previous study, Panidi *et al*. [26] conducted a meta-analysis and found that only high stretching volumes or intensities induce an increase in fascicle length, whereas low stretching volumes and intensities do not cause changes in muscle morphology. This suggests that total mechanical stress mediated by volume load and intensity is an important regulating factor for fascial length increase during static stretching. In our study, participants in the SST group performed static stretching at high volume and intensity, and these interventions are likely to have had a more comprehensive effect on overall hip ROM.

In this study, the FRT was performed primarily targeting

TABLE 2. Subjective hip function score (unit: score).

Section	SST (n = 17)		diff (%)	FRT (n = 17)		diff (%)	T × G
	Baseline	Post 6 wk		Baseline	Post 6 wk		*p*-value
HAGOS total	78.1 ± 6.2	88.4 ± 7.1[a]	13.2	78.5 ± 7.7	91.6 ± 3.4[a]	16.8	0.069
Symptoms	78.1 ± 6.1	85.3 ± 5.2[a]	9.2	78.8 ± 8.5	92.1 ± 2.5[a,b]	16.9	0.022
Pain	72.4 ± 7.5	81.1 ± 9.2[a]	12.0	73.2 ± 5.5	88.2 ± 6.6[a,b]	20.5	0.019
ADL	81.7 ± 7.2	89.7 ± 5.8[a]	9.8	80.9 ± 4.6	89.3 ± 5.0[a]	10.4	0.254
Sport and recreation	75.4 ± 6.3	92.4 ± 2.3[a]	22.5	77.9 ± 6.9	92.7 ± 3.5[a]	19.0	0.120
Physical activity	80.2 ± 7.7	90.6 ± 3.6[a]	13.0	78.3 ± 5.5	94.4 ± 3.1[a]	20.6	0.335
Quality of life	81.0 ± 6.2	91.5 ± 2.9[a]	13.0	81.6 ± 6.9	93.3 ± 3.5[a]	14.3	0.451

Data are expressed as mean ± standard deviation; [a], Baseline vs. Post 6 wk; [b], SST vs. FRT; SST, static stretching training; FRT, foam rolling training; wk, week; diff, different; HAGOS, hip and groin outcome scale; ADL, activities of daily living; T × G, time × group.

TABLE 3. Participant's hip range of motion (unit: degree).

Motion	SST (n = 17)		diff (%)	FRT (n = 17)		diff (%)	T × G
	Baseline	Post 6 wk		Baseline	Post 6 wk		*p*-value
Flexion	95.4 ± 8.7	120.8 ± 5.0[a]	25.8	92.7 ± 9.0	105.5 ± 3.6[a,b]	13.3	<0.001
Extension	18.1 ± 5.1	19.8 ± 4.6	9.4	17.8 ± 4.7	19.6 ± 4.5	10.1	0.505
Adduction	15.3 ± 4.5	16.7 ± 5.6	9.2	16.1 ± 3.7	17.7 ± 5.2	9.9	0.476
Abduction	33.1 ± 7.1	50.9 ± 4.6[a]	53.8	36.7 ± 2.4	44.8 ± 4.5[a,b]	22.1	0.020
Internal R.	30.2 ± 4.2	43.7 ± 4.8[a]	44.7	29.9 ± 4.8	38.0 ± 5.9[a,b]	27.1	0.005
External R.	48.4 ± 7.2	60.0 ± 8.3[a]	24.0	47.5 ± 7.5	50.6 ± 4.1[b]	6.5	0.229

Data are expressed as mean ± standard deviation; [a], Baseline vs. Post 6 wk; [b], SST vs. FRT; SST, static stretching training; FRT, foam rolling training; wk, week; diff, different; Internal R, Internal rotation; External R, external rotation; T × G, time × group.

TABLE 4. Dynamic balance (unit: cm).

Direction	SST (n = 17)		diff (%)	FRT (n = 17)		diff (%)	T × G
	Baseline	Post 6 wk		Baseline	Post 6 wk		*p*-value
Anterior	62.8 ± 6.1	74.7 ± 7.0[a]	18.9	63.9 ± 7.2	69.2 ± 7.1[a,b]	8.3	<0.001
Posteromedial	71.3 ± 11.3	86.3 ± 9.9[a]	21.0	70.8 ± 7.7	79.6 ± 8.8[a,b]	12.4	0.005
Posterolateral	72.5 ± 15.2	84.4 ± 16.0[a]	16.4	71.0 ± 6.1	78.4 ± 9.3[a,b]	10.4	0.011

Data are expressed as mean ± standard deviation; [a], Baseline vs. Post 6 wk; [b], SST vs. FRT; SST, static stretching training; FRT, foam rolling training; wk, week; diff, different; T × G, time × group.

TABLE 5. Isokinetic strength (unit: Nm/kg).

Movement	SST (n = 17)		diff (%)	FRT (n = 17)		diff (%)	T × G
	Baseline	Post 6 wk		Baseline	Post 6 wk		*p*-value
Flexion	145.5 ± 36.8	160.5 ± 32.4[a]	10.3	140.4 ± 38.7	174.9 ± 36.8[a,b]	24.6	0.006
Extension	212.7 ± 50.6	220.7 ± 48.6	3.8	210.5 ± 47.8	219.2 ± 46.9	4.1	0.258
Adduction	105.5 ± 21.3	110.9 ± 32.5	5.1	102.5 ± 42.4	108.4 ± 35.5	5.8	0.361
Abduction	113.4 ± 20.1	133.4 ± 26.1[a]	17.6	118.6 ± 23.2	149.8 ± 39.9[a,b]	26.3	0.019

Data are expressed as mean ± standard deviation; [a], Baseline vs. Post 6 wk; [b], SST vs. FRT; SST, static stretching training; FRT, foam rolling training; wk, week; diff, different; T × G, time × group.

the fascial layer and connective tissue surrounding the hip muscles, which may reduce fascial tightness and improve the tissue extensibility of muscles involved in joint movement [27]. Meanwhile, SST was performed to target the musculotendinous unit directly, promote elongation, and increase the length of muscle fibers over time. Unlike the immediate effects of foam rolling, the benefit of static stretching is that it accumulates over time, resulting in lasting changes in muscle length and flexibility [28]. These adaptations can significantly improve ROM across all hip movements, as observed in the SST group. However, because static stretching was implemented for a relatively short period in this study, the observed increase in ROM might primarily result from enhanced stretch tolerance, attributed to the adaptation of nociceptive nerve terminals, rather than structural changes in the muscle-tendon unit [14]. During static stretching, the Hoffman reflex inhibition occurs, reflecting a decrease in spinal cord excitability and reflexive responses to muscle stretching [29]. This reduction in motor neuron excitability in the spinal cord leads to decreased muscle tension, facilitating easier muscle stretching without discomfort and potentially increasing stretch tolerance [30]. Such adaptations enhance the efficacy of static stretching in improving flexibility and ROM.

The significant improvement in various HAGOS subscales as a result of FRT and SST demonstrates the various ways in which hip mobility restrictions can be improved. Foam rolling applies pressure to the fascia, which is the connective tissue surrounding muscles. This breaks down fascial adhesions and tender points, which can cause muscle tension and pain. This can help to significantly reduce symptoms of muscle imbalance or overuse-related discomfort or pain, which are common among soccer players. Furthermore, the mechanical pressure of foam rolling increases blood flow to the target area, which promotes tissue oxygenation [31]. This also promotes the elimination of metabolic waste and increases the delivery of oxygen and nutrients to muscle and fascial tissues. Improved tissue health *via* FRT may have contributed to the decrease in pain and symptoms reported in the HAGOS score. Meanwhile, active SST aims to improve flexibility by putting tension on stretch muscles and connective tissues [32]. SST's gradual stretching of muscle fibers may help relieve symptoms by reducing mechanical stress on muscles and tendons while increasing ROM. As reflected in the subscales of HAGOS, appropriate improvements could have been made in daily activities, sports and recreation. Although both FRT and SST were effective in improving subjective hip function, the particular benefits of FRT on symptom- and pain-related sub-scales may be linked to its multifaceted effects on fascial release, blood circulation, and pain modulation.

Dynamic balance and hip mobility are closely related, and there is a lot of evidence to support this connection [33]. This relationship is important for athletic performance and injury prevention, especially in sports that require quick and multidirectional movements such as soccer [8]. Teyhen *et al*. [34] reported that having high levels of hip ROM allows for wider strides, deeper squats, and wider reach, which all contribute to better balance during dynamic activities. Without proper hip mobility, athletes may compensate with less efficient movement strategies, which can compromise their balance and stability. Our study found that both FRT and SST groups showed improvement in reach distance in all directions of the Y-Balance Test Lower Quarter after the intervention. However, the SST group had significantly better results than the FRT group. This is because SST involves the modulation of muscle fiber lengthening, which may lead to improved neuromuscular adaptations [28]. Precise control of muscle activity allows for more accurate coordination during balance tasks, which may have contributed to the superior results seen in the SST group. Overall, hip flexibility is essential for maintaining and coordinating balance during dynamic tasks [33].

Although FRT may have a positive effect on dynamic balance through alleviating muscle stiffness and enhancing tissue elasticity [35], it is likely that it does not significantly expand dynamic balance to the same extent as SST. This is because FRT primarily provides short-term improvements in muscle function [13]. Therefore, FRT's primary contribution to balance may be its immediate effects on muscle relaxation and pain relief rather than long-term improvements in flexibility or proprioception [36]. The differential effects of FRT and SST on dynamic balance, particularly the more significant improvement in the SST group, are most likely due to the comprehensive effects on hip mobility, neuromuscular coordination, and proprioceptive abilities [28].

The isokinetic hip strength test revealed a significant improvement in strength, specifically in flexion and abduction, for both the FRT and SST groups. However, there were no significant differences in strength between the two groups, notably for extension and adduction. The notable improvement in hip flexion and abduction strength is likely due to a combination of increased flexibility, lessened pain, and the characteristics of the intervention applied. It should be noted that both the FRT and SST interventions were primarily designed to improve flexibility and ROM, rather than the direct strength of the muscles involved in hip movement. This result aligns with the principle of specificity in training [37]. In a recent study, Nakao *et al*. [38] investigated the chronic effects of a static stretching program on hamstring strength. The results showed that while passive stiffness decreased, peak torque remained unchanged after a 4-week static stretching intervention. This indicates that static stretching effectively reduced stiffness in the hamstring musculotendinous unit without adversely affecting maximal strength. Additionally, the study noted a post-intervention shift in the angle of peak torque during isokinetic strength testing to a greater knee extension angle. This shift suggests that static stretching can modify the torque-angle curve, highlighting its potential to influence the mechanics of muscle contraction. In another study, Lee *et al*. [39] investigated the effect of foam rolling on isokinetic muscle strength. The study found that foam rolling performed as part of a warm-up had an immediate effect on lower extremity strength, reporting a 33–35% increase in isokinetic knee strength. These results suggest that self-myofascial release through foam rolling can contribute to the improvement of muscular performance by stimulating both physiological and mechanical properties within the muscle, improving neuromuscular efficiency and relieving joint stress as a result of improving ROM.

Similarly, in our study, the participants' hip flexion and abduction strength increased after a 6-week static stretching and foam rolling intervention. Neither of the training interventions in this study was intended to increase strength. As a result, overall strength gains, including extension and adduction, were not observed in either group. However, the improvements in hip flexion and abduction strength are likely due to increased muscle recruitment efficiency resulting from improved ROM of the hip joint [40]. The results of this study showed that the most significant changes in hip ROM were observed in flexion and abduction movements, which may have contributed to the reduction in mechanical resistance caused by the FRT and SST interventions, allowing for more effective contraction in flexion and abduction. Furthermore, the FRT group showed greater strength improvement, which could be due to improved pain and symptom management. Pain is a critical cause of decreased muscle strength as it inhibits muscle activity. By alleviating the pain that accompanies hip flexion and abduction movements, this inhibitory effect may have been reduced, resulting in greater strength improvement [41].

Although our study yielded meaningful results, it also has several limitations. Firstly, the study only included male high school soccer athletes, which may limit the generalizability of the results to other athletes, sports and female athletes. Secondly, there are still limitations to extensive research on restricted hip ROM-related injuries, including causes, treatments and rehabilitation. Therefore, this study cannot provide a definitive answer. Thirdly, because the control group was not established and comparative effectiveness was not established, it cannot be confirmed that the intervention training in this study is superior to other intervention programs. Fourthly, we employed active static stretching techniques that participants could perform independently, aiming for interventions that could be seamlessly integrated into their training routines. However, the inclusion of additional passive stabilization techniques, such as pelvic stabilization provided by a therapist's hands or mechanical aids, might be necessary to ensure the consistent effectiveness and safety of the static stretching. Lastly, while this study conducted various measurements, the most important aspect of restricted ROM was the improvement of ROM. Therefore, to determine whether these variables are causal, it will be necessary to check whether there is a relationship between hip score, strength and dynamic balance depending on whether ROM is improved.

5. Conclusions

The study found that both FRT and SST interventions, which lasted for six weeks, were effective in improving flexion, internal rotation, and abduction in ROM, as well as the subjective hip function in youth soccer players with restricted hip ROM. Additionally, dynamic balance, flexion and abduction strength also improved. In particular, FRT was more effective in reducing symptoms and pain and improving muscle strength, while SST improved hip mobility and dynamic balance more broadly. Therefore, this study recommends recognizing the individual effects of FRT and SST and leveraging their complementary benefits through a tailored approach based on the individual needs of athletes.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the authors.

AUTHOR CONTRIBUTIONS

YK and MC—conceptualization, supervision. GFZ and YK—methodology, formal analysis, review and editing. MC—investigation. GFZ and MC—original draft writing. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Research Ethics Committee of the Gangneung-Wonju National University (GWNUIRB-R2021-11). The patient (or their parent or legal guardian in the case of children under 16) gave their written consent for examination and publication for the purpose of the study.

ACKNOWLEDGMENT

We would like to thank the Gangneung-Wonju national university for editing and administrative support.

FUNDING

This study was supported by Zhoukou Normal University High level Talent Research Initiation Funding Project (ZKNUC2022043).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Luo S, Soh KG, Zhang L, Zhai X, Sunardi J, Gao Y, *et al*. Effect of core training on skill-related physical fitness performance among soccer players: a systematic review. Frontiers in Public Health. 2023; 10: 1046456–1046469.

[2] AlTaweel A, Nuhmani S, Ahsan M, Abualait T, Muaidi Q. Determining the hip joint isokinetic muscle strength and range of motion of professional soccer players based on their field position. PeerJ. 2022; 10: e14000–e14013.

[3] Hölbling D, Baca A, Dabnichki P. A kinematic model for assessment of hip joint range-of-motion in fast sport movements using spreading angles. Sports Biomechanics. 2023; 22: 1243–1255.

[4] de Castro JV, Machado KC, Scaramussa K, Gomes JLE. Incidence of decreased hip range of motion in youth soccer players and response to a stretching program: a randomized clinical trial. Journal of Sport Rehabilitation. 2013; 22: 100–107.

[5] García-Pinillos F, Ruiz-Ariza A, Moreno del Castillo R, Latorre-Román PÁ. Impact of limited hamstring flexibility on vertical jump, kicking speed, sprint, and agility in young football players. Journal of Sports Sciences. 2015; 33: 1293–1297.

[6] Robles-Palazón FJ, Ayala F, Cejudo A, De Ste Croix M, Sainz de Baranda P, Santonja F. Effects of age and maturation on lower extremity range of motion in male youth soccer players. Journal of Strength and Conditioning Research. 2022; 36: 1417–1425.

[7] Angoorani H, Karaminia E, Mazaherinezhad A, Hassanmirzaei B, Moghadam N. Correlation of hip passive range of motion with lower limbs injuries in iranian professional soccer players. Journal of Clinical Physiotherapy Research. 2021; 6: e34–e41.

[8] Tak I, Engelaar L, Gouttebarge V, Barendrecht M, Van den Heuvel S, Kerkhoffs G, *et al*. Is lower hip range of motion a risk factor for groin pain in athletes? A systematic review with clinical applications. British Journal of Sports Medicine. 2017; 51: 1611–1621.

[9] Hogg JA, Waxman JP, Shultz SJ. Examining the effects of femoral anteversion and passive hip rotation on ACL injury and knee biomechanics: a systematic review and meta-analysis. Journal of Experimental Orthopaedics. 2022; 9: 40.

[10] Malina RM, Rogol AD, Cumming SP, Coelho e Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. British Journal of Sports Medicine. 2015; 49: 852–859.

[11] Chaari F, Boyas S, Sahli S, Fendri T, Harrabi MA, Rebai H, *et al*. Postural balance asymmetry and subsequent noncontact lower extremity musculoskeletal injuries among Tunisian soccer players with groin pain: a prospective case control study. Gait & Posture. 2022; 98: 134–140.

[12] Markovic G. Acute effects of instrument assisted soft tissue mobilization *vs.* foam rolling on knee and hip range of motion in soccer players. Journal of Bodywork and Movement Therapies. 2015; 19: 690–696.

[13] Nakamura M, Onuma R, Kiyono R, Yasaka K, Sato S, Yahata K, *et al*. The acute and prolonged effects of different durations of foam rolling on range of motion, muscle stiffness, and muscle strength. Journal of Sports Science & Medicine. 2021; 20: 62–68.

[14] Takeuchi K, Nakamura M, Konrad A, Mizuno T. Long-term static stretching can decrease muscle stiffness: a systematic review and meta-analysis. Scandinavian Journal of Medicine & Science in Sports. 2023; 33: 1294–1306.

[15] Siebert T, Donath L, Borsdorf M, Stutzig N. Effect of static stretching, dynamic stretching, and myofascial foam rolling on range of motion during hip flexion: a randomized crossover trial. Journal of Strength and Conditioning Research. 2022; 36: 680–685.

[16] Yanaoka T, Yoshimura A, Iwata R, Fukuchi M, Hirose N. The effect of foam rollers of varying densities on range of motion recovery. Journal of Bodywork and Movement Therapies. 2021; 26: 64–71.

[17] Thorborg K, Holmich P, Christensen R, Petersen J, Roos EM. The copenhagen hip and groin outcome score (HAGOS): development and validation according to the COSMIN checklist. British Journal of Sports Medicine. 2011; 45: 478–491.

[18] Thomeé R, Jónasson P, Thorborg K, Sansone M, Ahldén M, Thomeé C, *et al*. Cross-cultural adaptation to Swedish and validation of the Copenhagen Hip and Groin Outcome Score (HAGOS) for pain, symptoms and physical function in patients with hip and groin disability due to femoro-acetabular impingement. Knee Surgery, Sports Traumatology, Arthroscopy. 2014; 22: 835–842.

[19] Yazdifar M, Yazdifar MR, Mahmud J, Esat I, Chizari M. Evaluating the hip range of motion using the goniometer and video tracking methods. Procedia Engineering. 2013; 68: 77–82.

[20] Bennett H, Chalmers S, Milanese S, Fuller J. The association between Y-balance test scores, injury, and physical performance in elite adolescent Australian footballers. Journal of Science and Medicine in Sport. 2022; 25: 306–311.

[21] Hannon JP, Wang-Price S, Garrison JC, Goto S, Bothwell JM, Bush CA. Normalized hip and knee strength in two age groups of adolescent female soccer players. Journal of Strength and Conditioning Research. 2022; 36: 207–211.

[22] Bayles MP. ACSM's exercise testing and prescription. 2nd edn. Lippincott williams & wilkins: Philadelphia. 2023.

[23] Konrad A, Nakamura M, Paternoster FK, Tilp M, Behm DG. A comparison of a single bout of stretching or foam rolling on range of motion in healthy adults. European Journal of Applied Physiology. 2022; 122: 1545–1557.

[24] Junker DH, Stöggl TL. The foam roll as a tool to improve hamstring flexibility. Journal of Strength and Conditioning Research. 2015; 29: 3480–3485.

[25] Hinks A, Franchi MV, Power GA. The influence of longitudinal muscle fascicle growth on mechanical function. Journal of Applied Physiology. 2022; 133: 87–103.

[26] Panidi I, Donti O, Konrad A, Dinas PC, Terzis G, Mouratidis A, *et al*. Muscle architecture adaptations to static stretching training: a systematic review with meta-analysis. Sports Medicine-Open. 2023; 9: 47–73.

[27] Chang TT, Li Z, Zhu YC, Wang XQ, Zhang ZJ. Effects of self-myofascial release using a foam roller on the stiffness of the gastrocnemius-achilles tendon complex and ankle dorsiflexion range of motion. Frontiers in Physiology. 2021; 12: 718827–718835.

[28] Shah R, Samuel MW, Son J. Acute and chronic effects of static stretching on neuromuscular properties: a meta-analytical review. Applied Sciences. 2023; 13: 11979–112009.

[29] Trajano GS, Blazevich AJ. Static stretching reduces motoneuron excitability: the potential role of neuromodulation. Exercise and Sport Sciences Reviews. 2021; 49: 126–132.

[30] Konrad A, Tilp M. Increased range of motion after static stretching is not due to changes in muscle and tendon structures. Clinical Biomechanics. 2014; 29: 636–642.

[31] Schroeder J, Wilke J, Hollander K. Effects of foam rolling duration on tissue stiffness and perfusion: a randomized cross-over trial. Journal of Sports Science & Medicine. 2021; 20: 626–634.

[32] Amiri-Khorasani M, Sahebozamani M, Tabrizi KG, Yusof AB. Acute effect of different stretching methods on Illinois agility test in soccer players. Journal of Strength and Conditioning Research. 2010; 24: 2698–2704.

[33] Nakagawa TH, Petersen RS. Relationship of hip and ankle range of motion, trunk muscle endurance with knee valgus and dynamic balance in males. Physical Therapy in Sport. 2018; 34: 174–179.

[34] Teyhen DS, Shaffer SW, Lorenson CL, Greenberg MD, Rogers SM, Koreerat CM, *et al*. Clinical measures associated with dynamic balance and functional movement. Journal of Strength and Conditioning Research. 2014; 28: 1272–1283.

[35] Hendricks S, Hill H, Hollander SD, Lombard W, Parker R. Effects of foam rolling on performance and recovery: a systematic review of the literature to guide practitioners on the use of foam rolling. Journal of Bodywork and Movement Therapies. 2020; 24: 151–174.

[36] Glänzel MH, Rodrigues DR, Petter GN, Pozzobon D, Vaz MA, Geremia JM. Foam rolling acute effects on myofascial tissue stiffness and muscle strength: a systematic review and meta-analysis. Journal of Strength and Conditioning Research. 2023; 37: 951–968.

[37] Stone MH, Hornsby WG, Suarez DG, Duca M, Pierce KC. Training specificity for athletes: emphasis on strength-power training: a narrative review. Journal of Functional Morphology and Kinesiology. 2022; 7: 102–120.

[38] Nakao S, Ikezoe T, Nakamura M, Umegaki H, Fujita K, Umehara J, *et al*. Chronic effects of a static stretching program on hamstring strength. Journal of Strength and Conditioning Research. 2021; 35: 1924–1929.

[39] Lee C, Chu I, Lyu B, Chang W, Chang N. Comparison of vibration rolling, nonvibration rolling, and static stretching as a warm-up exercise on flexibility, joint proprioception, muscle strength, and balance in young adults. Journal of Sports Sciences. 2018; 36: 2575–2582.

[40] Bowman KF, Fox J, Sekiya JK. A clinically relevant review of hip biomechanics. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2010; 26: 1118–1129.

[41] Henriksen M, Rosager S, Aaboe J, Graven-Nielsen T, Bliddal H. Experimental knee pain reduces muscle strength. The Journal of Pain. 2011; 12: 460–467.

How to cite this article: Gaofei Zhang, Yonghwan Kim, Moonyoung Choi. Effects of foam rolling and static stretching training in youth soccer players with hip joint range of motion restriction. Journal of Men's Health. 2024; 20(7): 104-112. doi: 10.22514/jomh.2024.114.